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Comparison of Predictors of the Annoyance of Commuter, Stage II and Stage III Aircraft Overflights as Heard Outdoors

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ABSTRACT

Thirty audiometrically screened test participants judged the relative annoyance of two comparison (variable level) signals and thirty standard (fixed level) signals in an adaptive paired comparison psychoacoustic study. The signal ensemble included commuter, Stage II and Stage III aircraft overflights, as well as synthesized aircraft noise signatures. All test signals were presented for judgment as heard outdoors, in the presence of continuous background noise, under free-field listening conditions in an anechoic chamber. Analyses of the performance of 30 noise metrics as predictors of these annoyance judgments confirmed that the more complex metrics were generally more accurate and precise predictors than the simpler methods. EPNL was slightly less accurate and precise as a predictor of the annoyance judgments than a duration-adjusted variant of Zwicker's Loudness Level.

1 INTRODUCTION

A prior study (Pearsons, Howe, Sneddon, and Fidell, 1996, *q.v.*) closely related to the present study assessed the relative efficacy of several families of equivalent continuous sound level, maximum, and time-integrated noise metrics (*cf.* Table 1) as predictors of the annoyance of recorded flyovers as heard indoors. A principal finding of Pearsons *et al.* (1996) was that EPNL was slightly less accurate and precise as a predictor of annoyance judgments than a duration-adjusted variant of Zwicker's Loudness Level. Since EPNL serves as the unit for U.S. aircraft noise certification procedures under Part 36 of the Federal Aviation Regulations, further investigation of this finding was undertaken in the current study.

Although Loudness Level and EPNL values of aircraft overflight noise treat the spectral distribution of noise energy differently in several ways, a prominent difference between the two metrics is in their sensitivity to auditory masking of higher frequency energy by lower frequency energy. Loudness Level takes explicit account of this phenomenon, whereas EPNL does not. The current study explores the possibility that an overall spectral shaping given to all test signals by Pearsons *et al.* (1996) to simulate indoor listening conditions may have been associated with the slight improvement in predictability of annoyance judgments afforded by Loudness Level.

1.1 ORGANIZATION OF REPORT

Chapter 2 describes the influence of the findings of Pearsons *et al.* (1996) on the design of the present study. Chapter 3 describes the procedures used to select test signals and data collection methods used in this subjective judgment experiment. Chapters 4 and 5 present study results and discuss certain implications of the findings. Conclusions may be found in Chapter 6. A Glossary is provided in Chapter 9 for the benefit of readers unfamiliar with some of the terminology of regulatory acoustics. Appendix A contains instructions to test participants and the informed consent form signed by each prior to participation in the study. Appendix B contains additional graphic and tabular material relating to presentation levels. Appendix C contains tables of differences between levels of variable and fixed signals at judged equal annoyance for the 30 metrics.

Table 1 Names and abbreviations of average, maximum, and duration-adjusted noise metrics evaluated in present study

Spectral Weighting or Calculation	AVG	MAX	Integrated Level
A-Weighted Sound Level	TAVA	MXMA[2]	ASEL
B-Weighted Sound Level	TAVB	MXMB	BSEL
C-Weighted Sound Level	TAVC	MXMC	CSEL
D-Weighted Sound Level[1]	TAVD	MXMD	DSEL
E-Weighted Sound Level[1]	TAVE	MXME	ESEL
Overall Sound Level[1]	TAVOA	MXMOA	OASEL
Perceived Noise Level	TAVPNL	MXMPNL	EPNL(NT)[3]
Tone-Corrected Perceived Noise Level	TAVPNLT	MXMPNLT	EPNL[4]
Perceived Level (Stevens)[1]	TAVPLS	MXMPLS	PLSSEL
Loudness Level (Zwicker)[1]	TAVLLZ	MXMLLZ	LLZSEL

[1] Non-standardized measures.

[2] The time interval used for maximum sound level, 500 ms, was between fast (125 ms) and slow (1000 ms), hence MXM[edium]A.

[3] EPNL without tone correction.

[4] Aspects of current calculations not in strict compliance with standardized definitions:

a) an averaging time of 0.5 sec (rather than 1 sec);
b) a reference time of 1 sec (rather than 10 sec).

2 BACKGROUND

All signals presented for annoyance judgments by Pearsons *et al.* (1996) were filtered as shown in Figure 1. This measure was taken to simulate indoor listening conditions in a manner similar to the usual practice in earlier annoyance studies (*e.g.*, Kryter, 1959; Kryter and Pearsons, 1963; Pearsons, 1968). A bias error was noted by Pearsons *et al.* (1996) in all of the metrics used to predict the point of subjective equality for the pairs of sounds presented to the subjects: the two variable signals, 727T and SIMT, were on average 2 to 6 dB higher in level than the fixed aircraft flyover signals when judged by the subjects to be equally annoying.

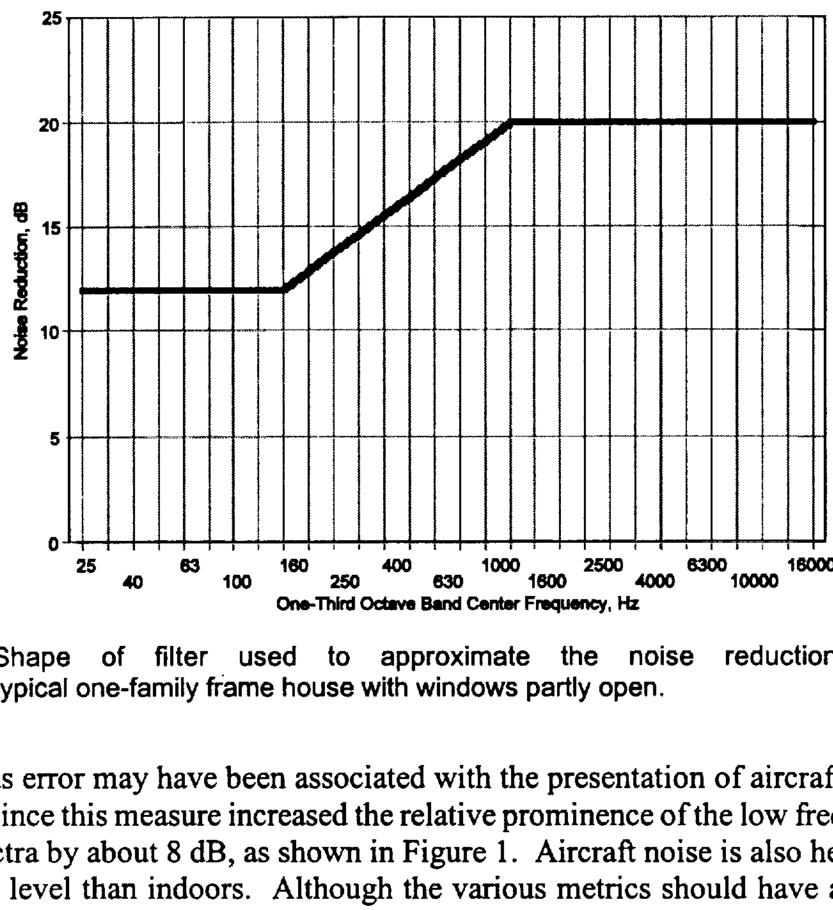

Figure 1 Shape of filter used to approximate the noise reduction provided by a typical one-family frame house with windows partly open.

This bias error may have been associated with the presentation of aircraft flyover noise as heard indoors, since this measure increased the relative prominence of the low frequency portion of the flyover spectra by about 8 dB, as shown in Figure 1. Aircraft noise is also heard outdoors at a higher absolute level than indoors. Although the various metrics should have accounted for the greater emphasis of low frequencies and the higher absolute level of the test signals, a further empirical test of the annoyance of flyovers as heard outdoors was undertaken. Signals in the present study were presented for judgment as heard outdoors; that is, as recorded in the field, without any further intentional spectral shaping.

3 METHOD

This chapter describes the procedures used to process and calibrate test signals, and the data collection methods used to determine points of subjective equality of annoyance among them. Unless otherwise noted, data acquisition conditions of the present study were identical to those of Pearsons *et al.* (1996). Parts of the text of Pearsons *et al.* (1996) are paraphrased here for the reader's convenience.

3.1 SELECTION OF TEST SIGNALS

Table 2 summarizes the recorded flyovers and other signals presented for annoyance judgments in the current study.

Table 2 Signals selected for paired comparison judgments.

SIGNAL SOURCE	ABBREVIATION			
Stage III Aircraft	**Landing**		**Takeoff**	
Boeing B737-300	733L		733T	
Boeing B747	747L		747T	
Boeing B757	757L		757T	
Boeing B767	767L		767T	
Boeing B777			777T	
Lockheed L1011	101L	101S*	101T	
McDonnell Douglas DC10	D10L		D10T	
McDonnell Douglas MD11	M11L		M11T	
McDonnell Douglas MD82			M82T	
Commuter Aircraft	**Landing**		**Takeoff**	
BAEJetstream 31	J31L		J31T	
de Havilland Dash-8			DS8T	
Stage I and II Aircraft and Other Sources	**Landing**		**Takeoff**	**Flyovers**
Boeing B707 (Stage II)	707L			
Boeing B727 (Stage II)	727L		727T	
Douglas DC7B (Stage I)	DC7L			
Douglas DC8(J) (Stage I)			DC8T	
Simulated Aircraft Noise(short duration)			SIMT	
Simulated Aircraft Noise Stage-X	ST5L		ST6T	
USAF B1B Flyover				B1BF
USAF F111 Flyover				F11F

*Spectrum modified to accentuate tone.

Table 3 List of identification numbers and test signals.

ID #	Abbr.	ID #	Abbr.
1	101L	16	DS8T
2	101T	17	D10L
3	707L	18	D10T
4	727L	19	DC7L
5	727T	20	DC8T
6	733L	21	F11F
7	733T	22	J31L
8	747L	23	J31T
9	747T	24	M11L
10	757L	25	M11T
11	757T	26	M82T
12	767L	27	SIMT
13	767T	28	ST5L
14	777T	29	ST6T
15	B1BF	30	101S

3.2 MEASUREMENT OF TEST SIGNALS

All signals were measured at nominal presentation levels at test participants' head position with a B&K Type 4155 (0.5") electret microphone and a B&K 2134 Sound Intensity Analyzer functioning as a real-time spectrum analyzer. One-third octave band sound pressure levels between 25 Hz and 20 kHz produced by the spectrum analyzer were sampled every half second and stored as digital time history files. These files subsequently served as the basis for calculation of the noise metrics summarized in Table 1.

3.3 TEST SUBJECTS

Participants were audiometrically screened to within 20 dB of normal hearing (audiometric zero) over the frequency range of 100 to 6,000 Hz prior to testing. All were retested at the end of their sixth session. No substantive changes in hearing were observed upon completion of the judgment tests. Fifteen of the thirty test participants who judged the relative annoyance of the test signals were women ranging in age from 18 to 52, while fifteen were men ranging in age from 18 to 45. The average age of both female and male participants was 25 years. The thirty test participants completed all six planned sessions.

3.4 SOLICITATION OF ANNOYANCE JUDGMENTS

A paired comparison procedure was adopted to permit direct and immediate judgments of the relative annoyance of test signals. Subjects seated approximately one meter in front of a loudspeaker in an anechoic chamber were instructed to judge whether the first or second signal presentation of each trial was the more annoying. Figure 2 shows the temporal sequence of

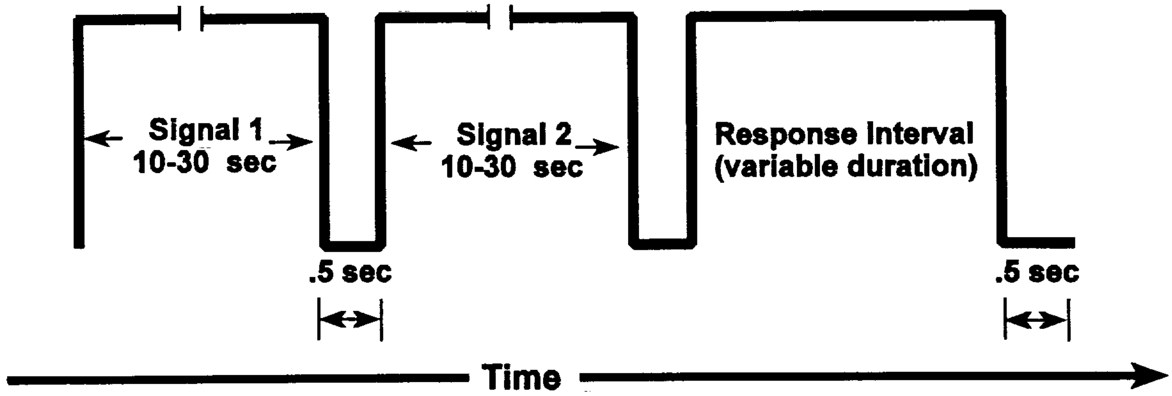

Figure 2 Temporal sequence of intra-trial intervals.

intra-trial intervals. The durations of the signal presentation intervals were determined by the durations of the signals themselves. The duration of the response interval was determined by the test participant's response latency. Test subjects in the study of Pearsons *et al.* (1996) had conducted 8 practice trials prior to the main experiment. Because analyses of these earlier results revealed no meaningful difference between the trial and the experimental sessions, no practice trials were administered in the current study.

Signal generation and presentation, as well as all other aspects of data collection, were under real-time computer control. Figure 3 diagrams the signal generation and presentation hardware. A maximum likelihood estimation algorithm described by Green (1990, 1995) and by Zhou and Green (1995) adaptively controlled signal presentation levels in real time, on the basis of test participants' ongoing decisions. The underlying psychometric function was assumed to be a cumulative Gaussian with a standard deviation of 10 dB. The value of the estimated point on the psychometric function was 50%: the point of subjective equality of annoyance, at which individual test subjects rated the comparison (variable level signal) more annoying 50% of the time and the standard (fixed level) signal more annoying 50% of the time.

This point was approached by a binary search algorithm. The maximum step size permitted between trials was 40 dB, while the minimum step size was 0.5 dB. The maximum permissible signal presentation level was approximately 100 dB. Twelve trials were administered for each determination of the relative annoyance of signal pairs, sufficient to yield a standard deviation of the threshold estimate of approximately 4 dB.

A subset of the data (about half of the subjects for 8 signals) was collected in comparisons of twenty rather than twelve trials. This measure was taken to determine whether the greater number

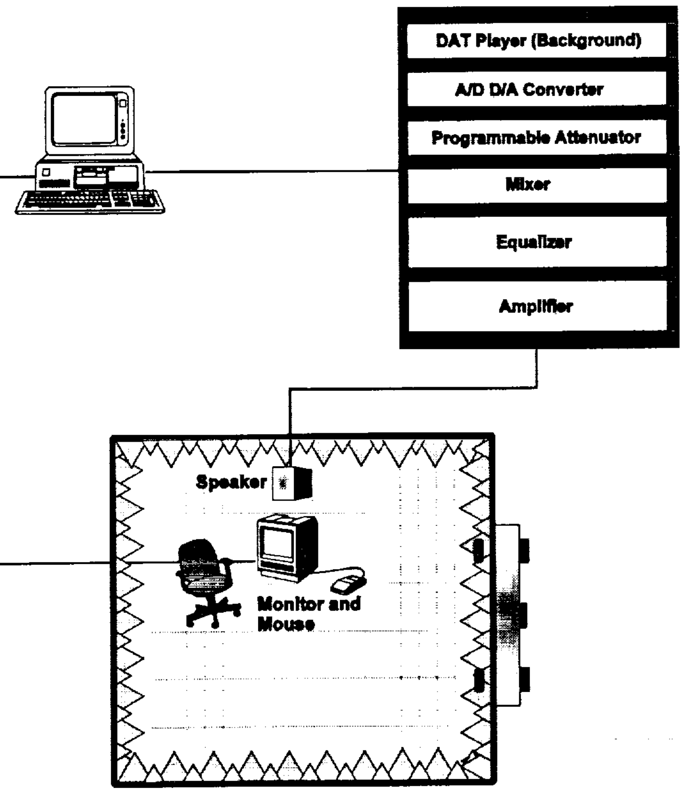

Figure 3 Diagram of adaptive signal generation and response recording system.

of trials would yield a less biased or more accurate estimate of the point of subjective equality of annoyance between the fixed and variable level signals.

The annoyance of all 30 standard (fixed level) test signals was judged relative to that of two comparison (variable level) test signals. One of the comparison (variable level) signals was a B-727 takeoff, while the other was a short duration (10 sec) simulation of an aircraft takeoff. The order of presentation of the fixed and variable signals was random on a trialwise basis. The order of presentation of signal pairs was independently randomized and fully interleaved. Testing was conducted in separate sessions lasting approximately 25 minutes each.[1] Test participants were required to leave the anechoic chamber between testing sessions. Their instructions may be found in Appendix A.

A highly compressed, long-term digital recording of general urban noise mixed with shaped Gaussian noise was reproduced at all times that test participants were present in the anechoic chamber. The A-level of the background noise at the test participant's head position was approximately 50 dB. Figure 4 shows the spectral shape of the background noise averaged over a 1 hour period.

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[1] Since test participants were not forced to respond within a fixed duration response interval, the pace of data collection varied slightly from session to session.

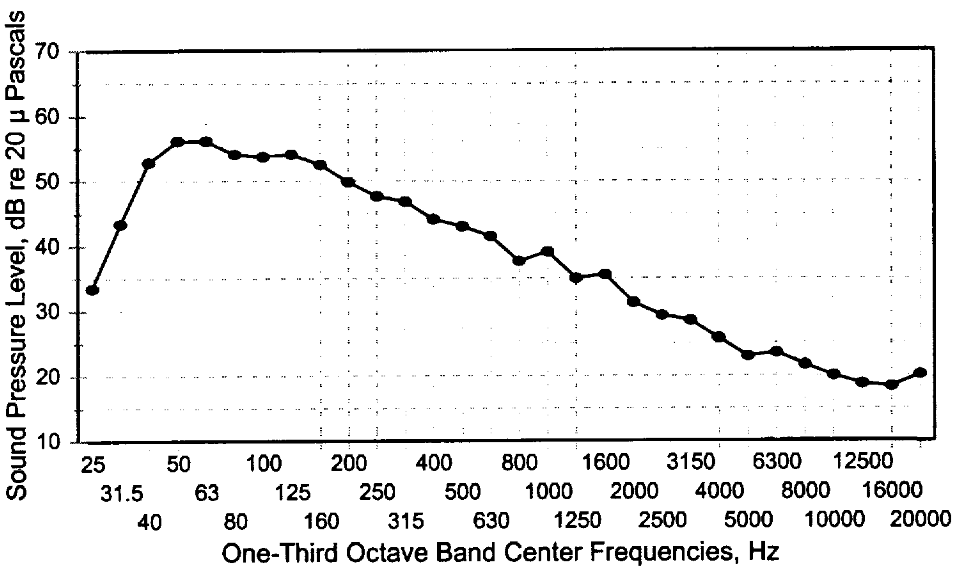

Figure 4 Spectrum of simulated urban background noise heard at all times that test participants were present in the anechoic chamber.

4 RESULTS

This section describes the findings of the paired comparison judgments against the two variable level signals.

4.1 DATA COLLECTION AND PROCESSING

4.1.1 Data Screening

The 25,680 paired comparison judgments collected during testing permitted 2,100 potential determinations of points of subjective equality of annoyance. The basic datum analyzed was the noise level of a variable signal when judged equal in annoyance to each fixed test signal. Two sequences of fewer than 12 signal presentations occurred, either because of participants' inattention or because the limits of the signal presentation levels were exceeded. These sequences were eliminated from consideration, leaving 2,098 judgments of points of subjective equality of annoyance of fixed level and variable level signals for analysis.

4.2 TIME HISTORY OF TRIALS

Figure 5 shows the successive presentation levels of a pair of signals presented to sixteen test subjects for annoyance judgment throughout a set of twenty trials. The initial difference in level of the pair of signals was pre-set on first presentation at 15 dB. In this case, the level (MXMA) of 727T was 15 dB higher than the level (MXMA) of 727L.

Differences in presentation levels on subsequent trials were determined by the test participants' annoyance judgments. Since all of the participants judged 727T to be more annoying than 727L on first presentation, at the second presentation of the pair of signals the level of 727T was reduced by 40 dB to a level 25 dB below the 727L. The participants then judged 727L to be the more annoying. At the third presentation, the level of 727T was increased by 20 dB, resulting in a difference of 5 dB between the pair of signals (that is, 727T was presented 5 dB lower in level than 727L).

Participants were no longer unanimous about which of the two signals was the more annoying at the third presentation of the pair of signals. For those who judged 727T to be more annoying, 727T was reduced by 10 dB at the fourth trial, resulting in a difference in presentation level of 15 dB. For those who judged 727L to be more annoying, 727T was increased by 10 dB at the fourth trial, resulting in a difference in presentation level of 5 dB. This process continued through the 20th trial, to yield an average difference in presentation levels of 2.2 dB, reported as the subjective point of equality.

The average difference at 12 trials was 1.4 dB in this example. At 20 trials the average difference was 2.2 dB. The use of 12 trials as a basis for determining the point of subjective equality was considered reasonable since the difference in the two averages was small (0.7 dB) with respect to the standard deviation of the sixteen subjects' judgments. Table 4 shows similar summary results for 7 other signal pairs, further confirming that 12 trials sufficed as a reasonable basis for determining the point of subjective equality of annoyance. (Estimates of the point of subjective equality were nonetheless based on the entire set of trials — either 12 or 20 — since reducing the numbers of trials to 12 did not significantly affect the reported levels of the point of subjective equality.)

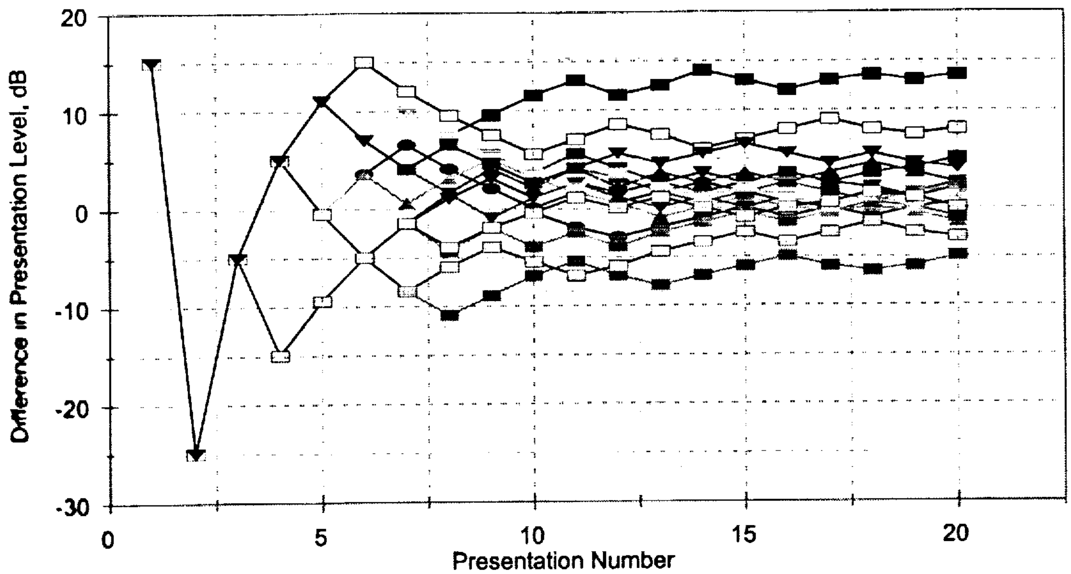

Figure 5 Differences in presentation levels of signals 727T and 727L for 20 successive trials of 16 test participants.

Table 4 Summary of differences in presentation levels of 727T or SIMT and test signal at 12 and at 20 trials.

SIGNAL ID	NUMBER OF TEST PARTICIPANTS (SUBSET)	AVERAGE DIFFERENCE (in dB)			NUMBER OF TEST PARTICIPANTS (ALL)	AVERAGE DIFFERENCE (in dB)	
		At 12 trials	At 20 trials	Difference between results for 20 and 12 trials		At 12 trials	Difference between results for "all" and "subset" of test participants
727L-7*	16	1.4	2.2	0.7	30	2.0	-0.2
747L-S	14	7.0	6.7	-0.4	30	7.3	0.6
767L-S	16	9.8	9.6	-0.2	30	8.8	-0.8
818F-7	14	2.5	0.9	-1.6	30	0.0	-0.9
DS8T-S	16	5.5	5.2	-0.3	30	5.4	0.2
D10L-7	14	8.3	8.6	0.4	30	8.9	0.3
DC7L-S	14	5.6	5.3	-0.3	30	5.8	0.5
101S-7	16	8.7	9.8	1.1	30	6.7	-3.1
	Grand Average Difference			-0.1	Grand Average Difference		-0.4

* The character following the hyphen designates the variable test signal ("7" = 727T; "S" = SIMT) judged more or less annoying than the fixed signal (designated by the first four characters).

4.3 FORM OF GRAPHIC DATA PRESENTATION

Grand means for all test participants for points of subjective equality of annoyance are plotted throughout this report as differences between the level of the variable signal and that of the fixed signal to which it was judged equally annoying. The magnitudes of these differences vary for the 30 noise metrics calculated for each signal. A noise metric that perfectly predicted annoyance would exhibit a 0 dB difference between the variable and fixed signals at the point of subjective equality of annoyance.

Figure 6 plots (as filled circles) grand mean differences for determinations of the points of subjective equality between both variable signals (B-727 takeoff and the simulated aircraft takeoff) and all fixed test signals (on the ordinate) against noise metrics (on the abscissa). The extrema about each filled circle shows the range of ± 1 standard deviation for all comparisons. Figures 7 and 8 are comparable graphs showing similar trends for the two comparison signals separately. The noise metrics are ordered on the abscissa in groups of three. Within groups, the leftmost value plotted is the average metric, the middle value is the maximum metric, and the rightmost is the time integrated metric. Groups of metrics are positioned along the abscissa in rough order of accuracy of prediction, with the least accurate metrics toward the left of the figure and the most accurate metrics toward the right.

Figure 9 shows points of subjective equality of annoyance of test signals judged against themselves. Figure 9 arbitrarily displays the results in terms of differences in maximum A-weighted level (MXMA); since the two signals compared are identical, any other metric would show the same pattern. The average differences of less than 1 dB for 30 test participants demonstrate the accuracy of the maximum likelihood estimation algorithm for determining points of subjective equality of annoyance in paired comparison testing.

The repeatability of annoyance judgments by this method was also confirmed empirically. A subset of the signals was repeated during the test for all or a subset of test participants. A list of the test signals is shown in Table 5. The table also shows the difference between the comparison signal and the standard signal in terms of MXMA for the initial, second and third sets of trials, and the number of trials and participants associated with the results. Figure 10 illustrates the results in graphical form, plotting the repeat results against initial results. The sloping line in the figure represents perfect replication. Grand mean differences in points of subjective equality of annoyance for repeated determinations with the same signal pairs were typically less than 1 dB.

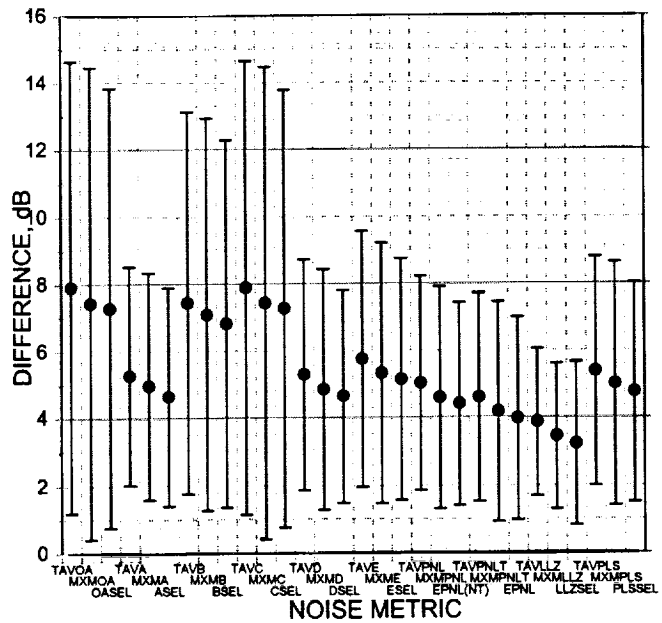

Figure 6 Average difference (±1 standard deviation) in noise metric of all test signals when judged equally annoying to both 727T and SIMT [(727T - test signal) and (SIMT - test signal)].

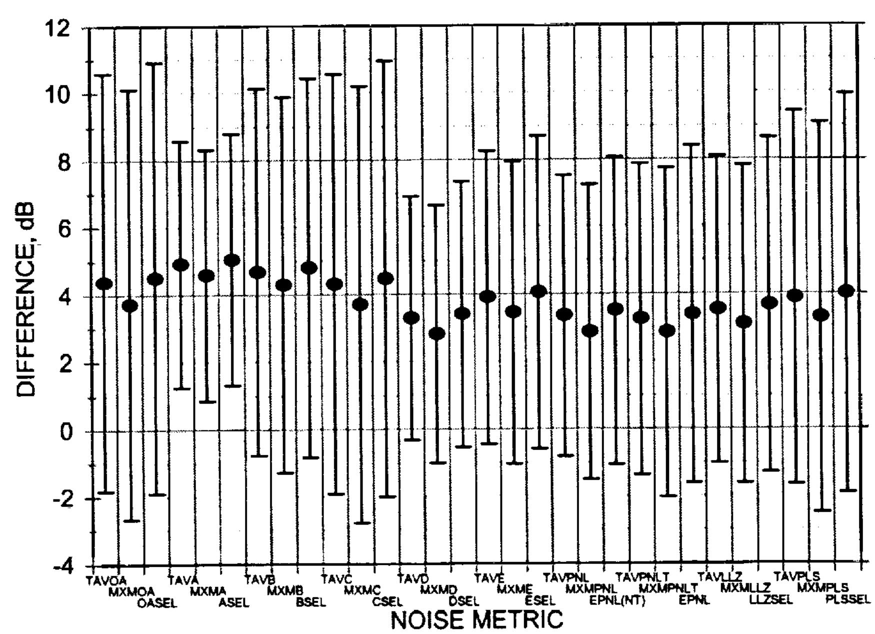

Figure 7 Average difference (±1 standard deviation) in noise metric of all test signals when judged equally annoying to 727T (727T - test signal).

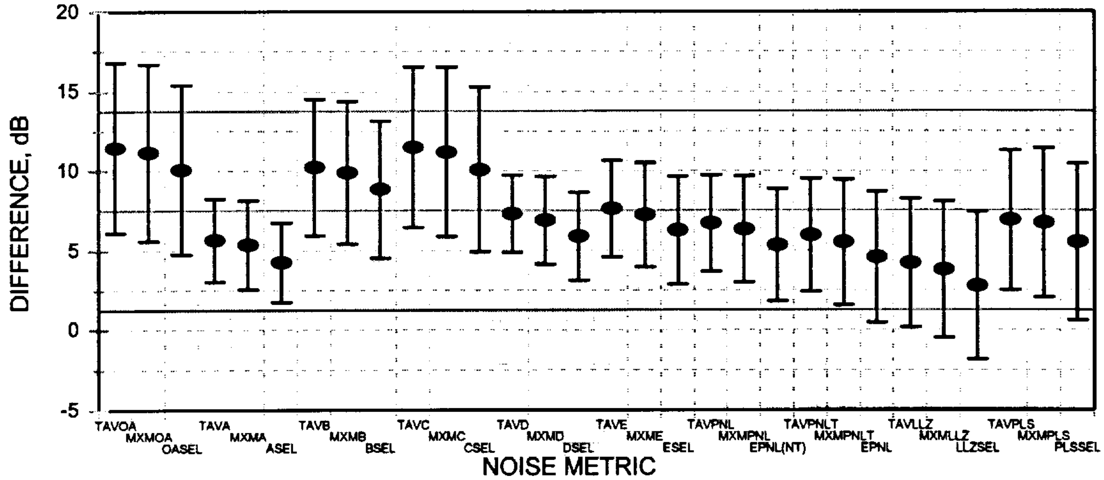

Figure 8 Average difference (±1 standard deviation) in noise metric of all test signals when judged equally annoying to SIMT (SIMT - test signal).

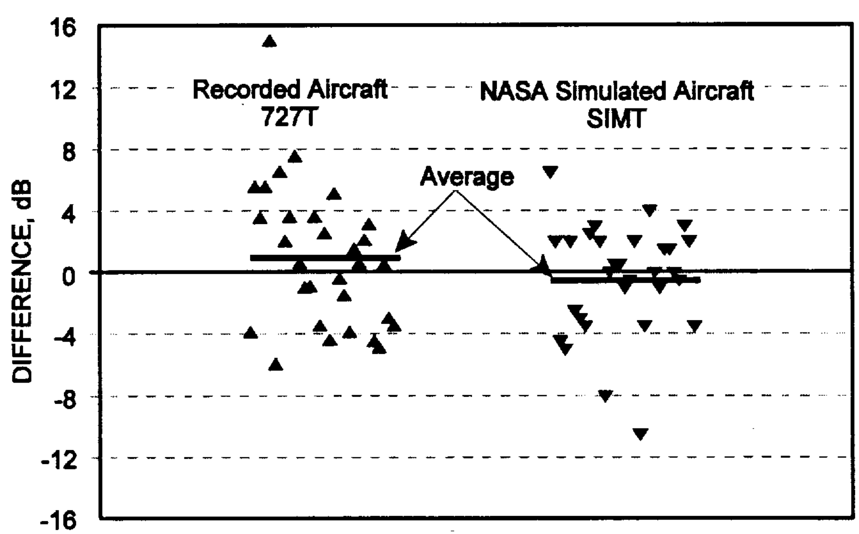

Figure 9 Differences in A-level of the same test signal when judged equally annoying to itself.

Table 5 Comparison of repeated results for selected test signals in terms of differences in MXMA [(727T or SIMT) - test signal].

	INITIAL RESULTS			SECOND RESULTS			THIRD RESULTS			DIFFERENCE BETWEEN INITIAL AND SUBSEQUENT RESULTS	
SIGNAL ID	Participants	Trials	Difference	Participants	Trials	Difference	Participants	Trials	Difference	Second	Third
727L-7	30	12	1.92	16	20	2.16				0.24	
747L-S	30	12	7.22	14	20	6.65				-0.57	
767L-S	30	12	8.60	30	12	8.15	16	12	8.51	-0.45	-0.09
767T-S	30	12	6.84	30	12	7.99				1.15	
B1BF-7	30	20	-0.22	14	20	0.61				0.82	
DS8T-S	29	12	5.05	16	20	5.21				0.16	
D10L-7	30	12	9.39	14	20	8.64				-0.75	
DC7L-S	30	12	6.51	14	12	3.33				-3.18	
M11L-7	30	12	7.86	30	12	7.71				-0.15	
SIMT-7	30	12	-1.12	30	12	-2.76				-1.64	
ST5L-S	30	12	8.12	30	12	9.35				1.23	
101S-7	30	12	6.01	30	12	5.96	16	20	10.51	-0.04	4.50
Average	29.92	12.67	5.52	22.33	15.33	5.25				-0.26	2.20

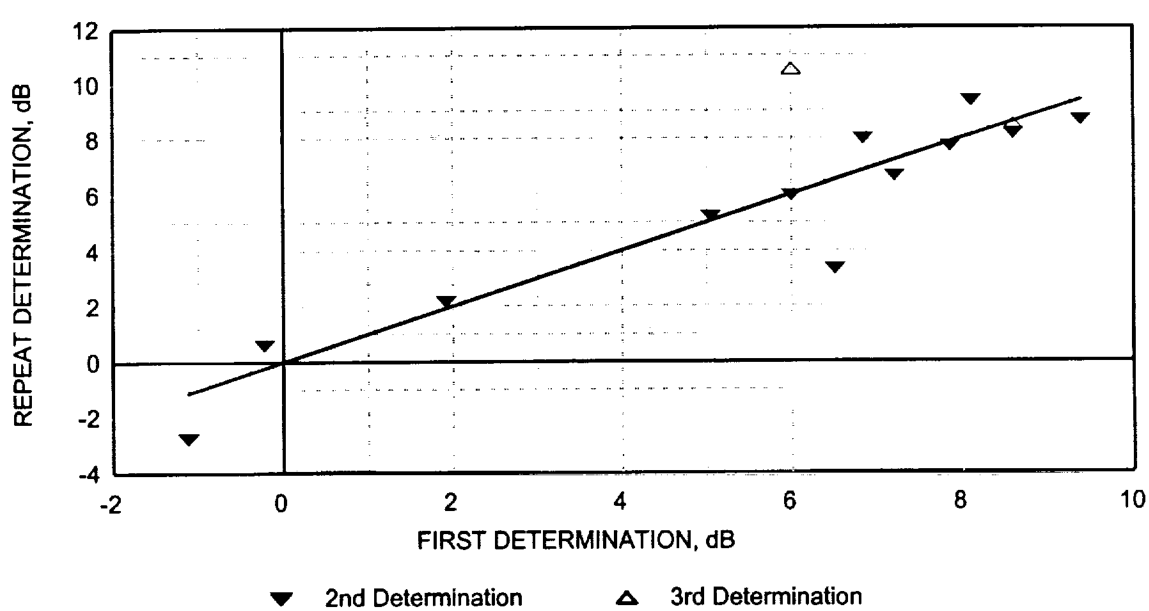

Figure 10 Comparison of repeat determinations with first determinations of differences between 727T or SIMT and test signal at judged equal annoyance.

4.4 DETAILS OF PAIRED COMPARISON JUDGMENTS

Findings are plotted in the remainder of this report in terms of the three noise metrics of greatest practical concern: Maximum A-level (MXMA), Effective Perceived Noise Level (EPNL), and a sound exposure type of measure based on Zwicker's Loudness Level (LLZSEL). The first metric was selected as a simple and widely understood one; the second because it is the metric of choice in aircraft noise certification; and the third because it exhibited the smallest differences between standard and comparison signals at points of subjective equality of annoyance. Appendix C contains complete tables of these points of subjective equality of annoyance averaged over all test participants for the convenience of readers wishing to analyze these findings in other ways.

4.4.1 Comparisons Against the B-727 Takeoff

Points of subjective equality of annoyance for each of the thirty individual test participants are plotted in Figure 11 for comparisons made against the recorded B-727 takeoff as a general indication of the range of judgments. (Note that many of the individual data points are plotted over one another.) The results are plotted in terms of MXMA for each of the test signals identified in Tables 2 and 3. Figure 11 also contains the comparison of this signal against itself (at Signal 5), with somewhat smaller dispersion of judgments than for other signals.

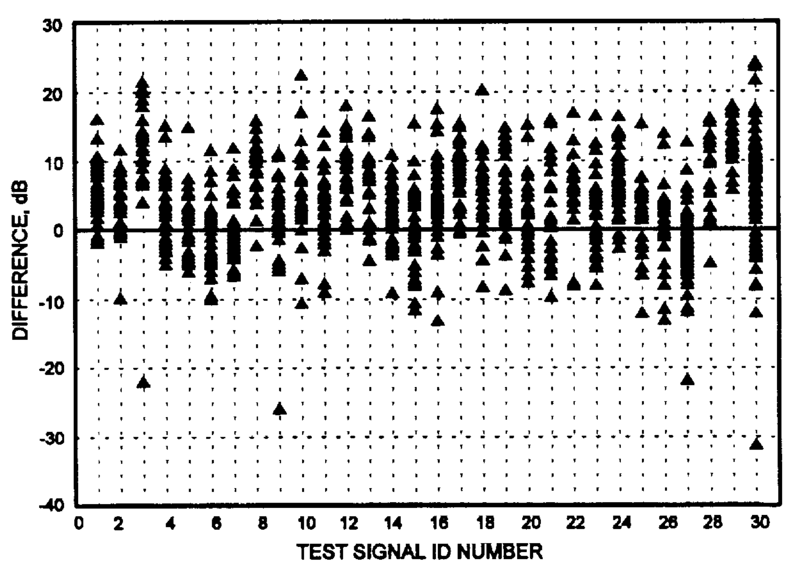

Figure 11 Difference in maximum A-level of the test signal when judged equally annoying to 727T (727T - test signal).

Figures 12 through 17 show grand means of points of subjective equality of annoyance results for the 30 test signals, separated by operation type and noise source category as shown in Table 2. Two graphs are presented for each noise metric. Figures 12 and 13 show the averaged results in terms of MXMA, Figures 14 and 15 show the averaged results in terms of EPNL, and Figures 16 and 17 show the averaged results in terms of LLZSEL. The first of the graphs in each set presents findings for comparisons of takeoffs, and the second for comparisons of landings and flyovers. Test signals corresponding to Stage I aircraft are presented first, followed by those for Stage II and III and commuter (turboprop) aircraft. Comparisons involving simulated future aircraft for which only simulations of takeoffs and landings were available are presented last. The results are ordered by decreasing EPNL differences within each aircraft stage, regardless of the metric under consideration.

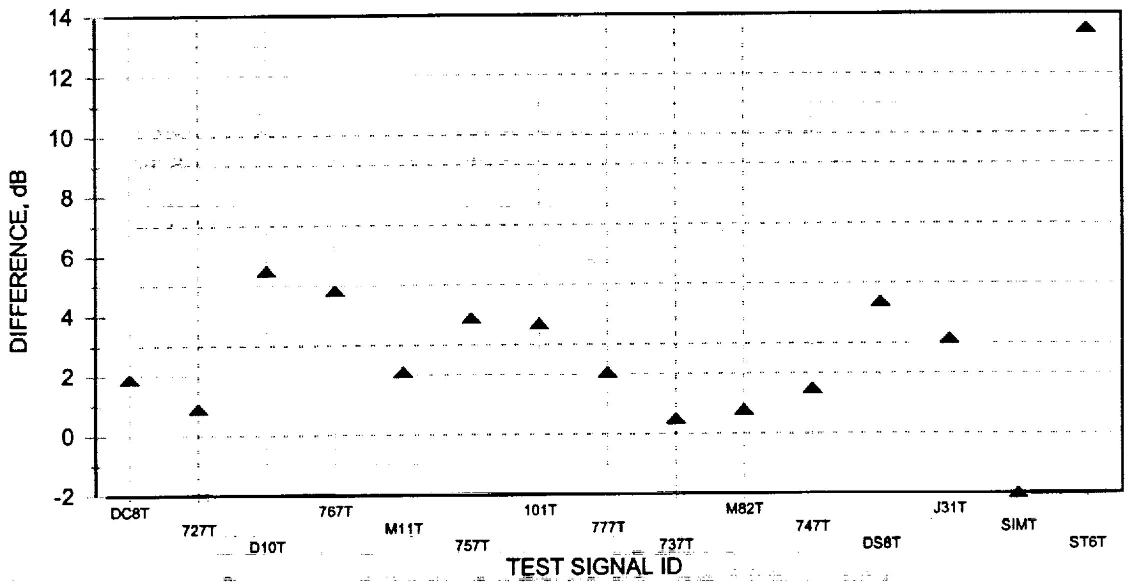

Figure 12 Results for takeoffs in terms of differences in MXMA of the pairs of signals when 727T is judged equally annoying to the test signal (727T - test signal).

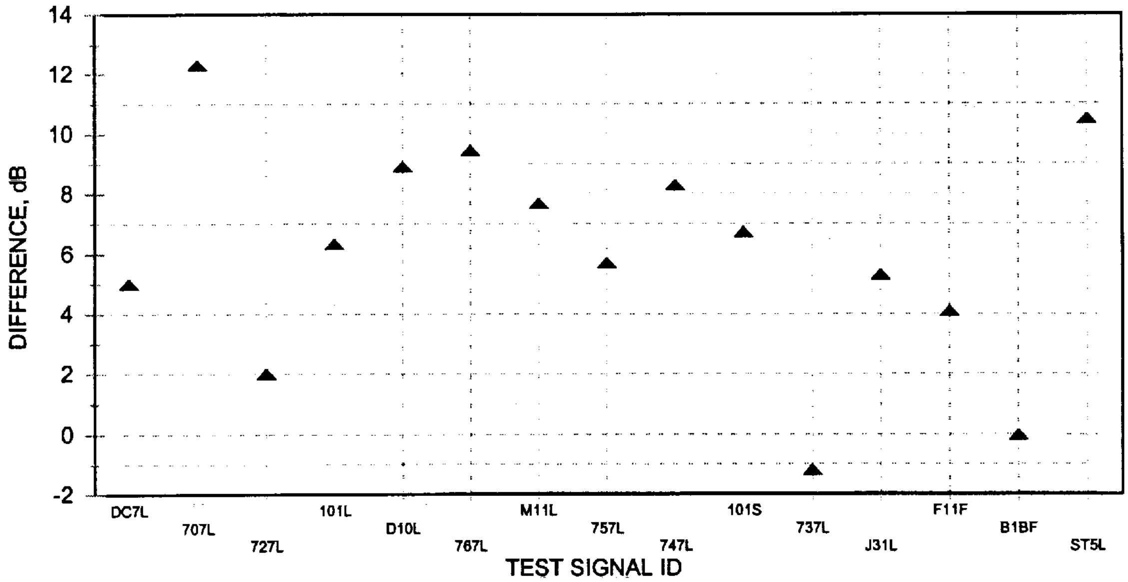

Figure 13 Results for landings in terms of differences in MXMA of the pairs of signals when 727T is judged equally annoying to the test signal (727T - test signal).

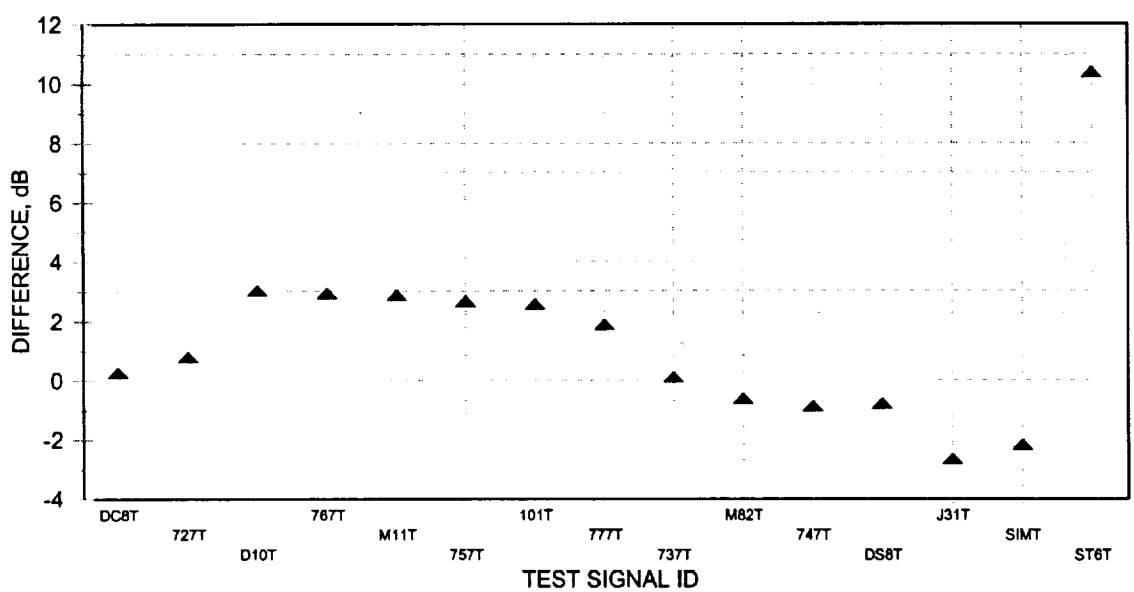

Figure 14 Results for takeoffs in terms of difference in EPNL of the pairs of signals when 727T is judged equally annoying to the test signal (727T - test signal).

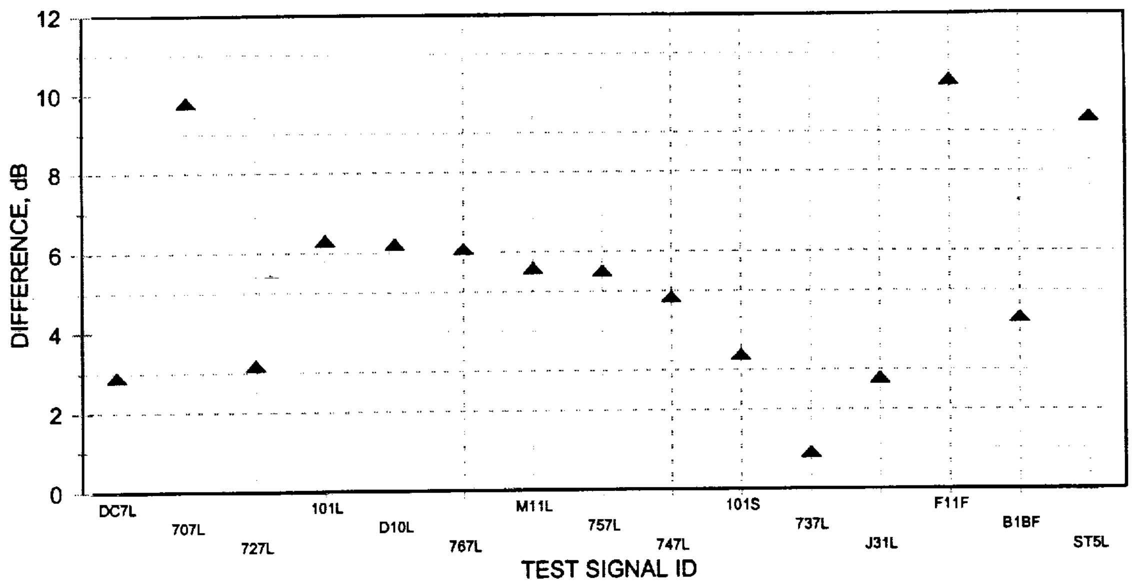

Figure 15 Results for landings in terms of differences in EPNL of the pairs of signals when 727T is judged equally annoying to the test signal (727T - test signal).

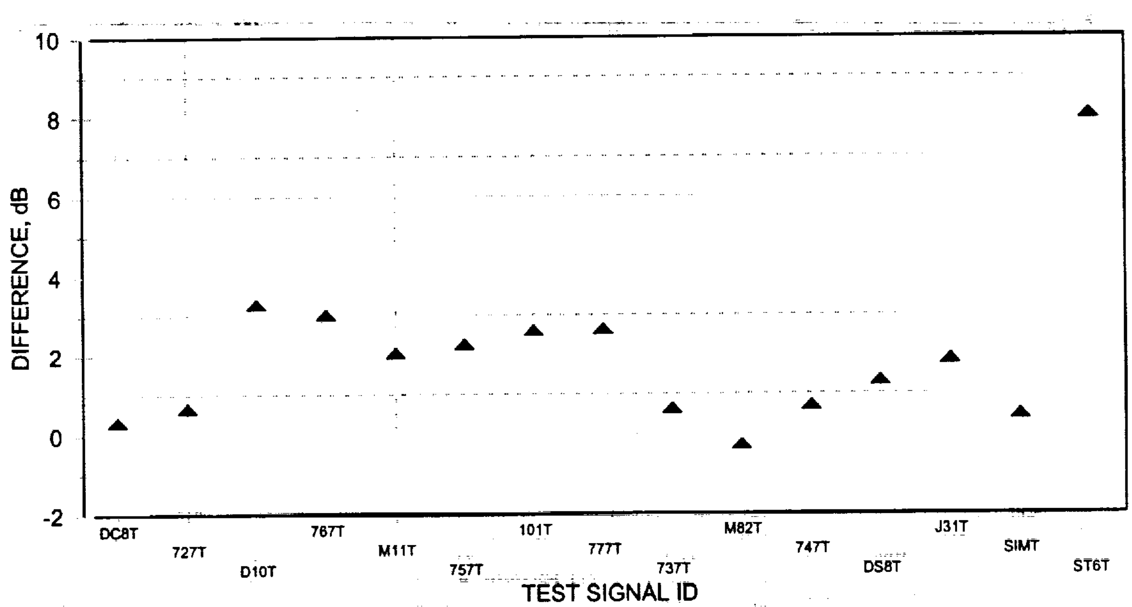

Figure 16 Results for takeoffs in terms of differences in LLZSEL of the pairs of signals when 727T is judged equally annoying to the test signal (727T - test signal).

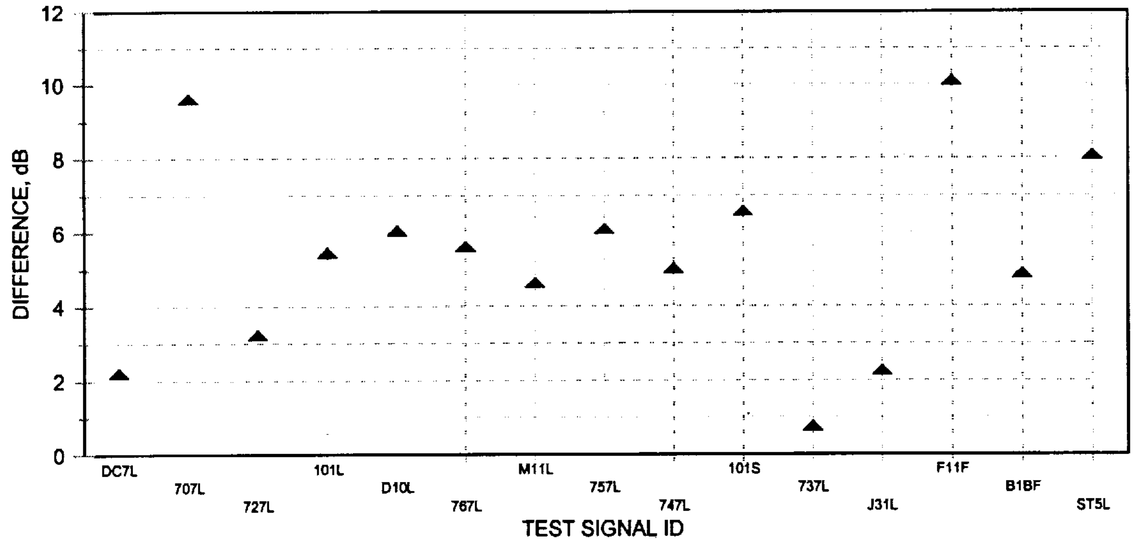

Figure 17 Results for landings in terms of differences in LLZSEL of the pairs of signals when 727T is judged equally annoying to the test signal (727T - test signal).

4.4.2 Comparisons Against the Simulated Aircraft Takeoff Signal

Figures 18 through 24 show averaged judgments of points of subjective equality of annoyance for comparisons against the simulated aircraft takeoff. Figure 18 summarizes findings in terms of MXMA for cases in which the takeoff was compared to the various fixed signals. Signal identification numbers for the fixed signals correspond to those listed in Tables 2 and 3. Figures 19 and 20 show the averaged results for each of the test signals in terms of MXMA. Figures 21 and 22 and Figures 23 and 24 show the averaged results for EPNL and LLZSEL, respectively.

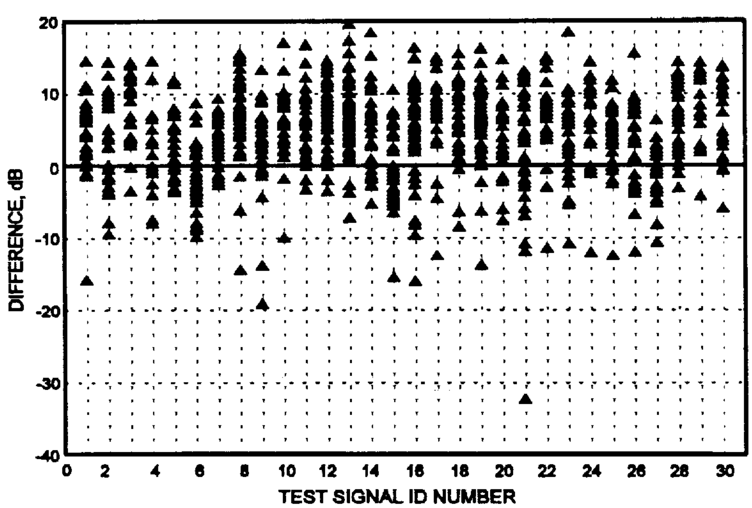

Figure 18 Difference in maximum A-level of the test signal when judged equally annoying to SIMT (SIMT - test signal).

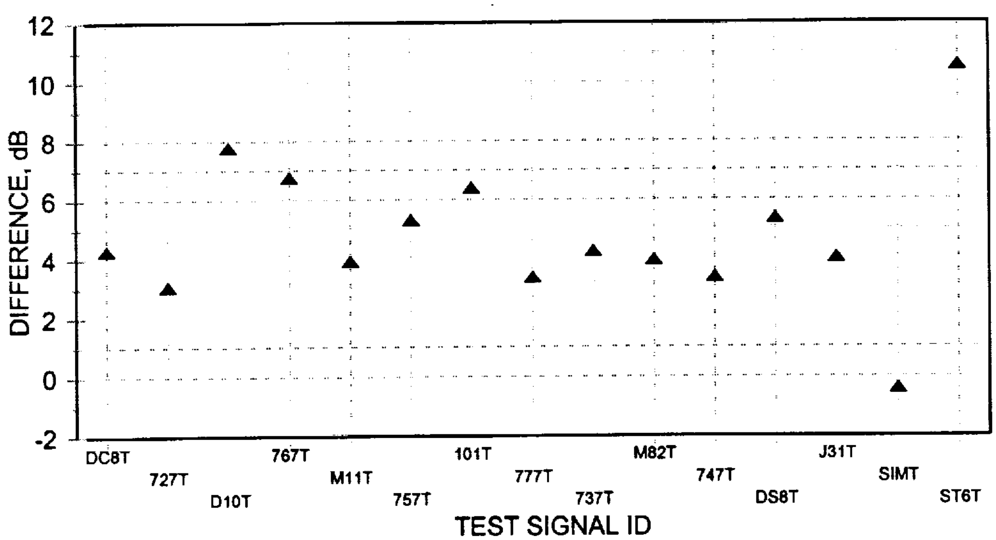

Figure 19 Results for takeoffs in terms of differences in MXMA of the pairs of signals when SIMT is judged equally annoying to the test signal (SIMT - test signal).

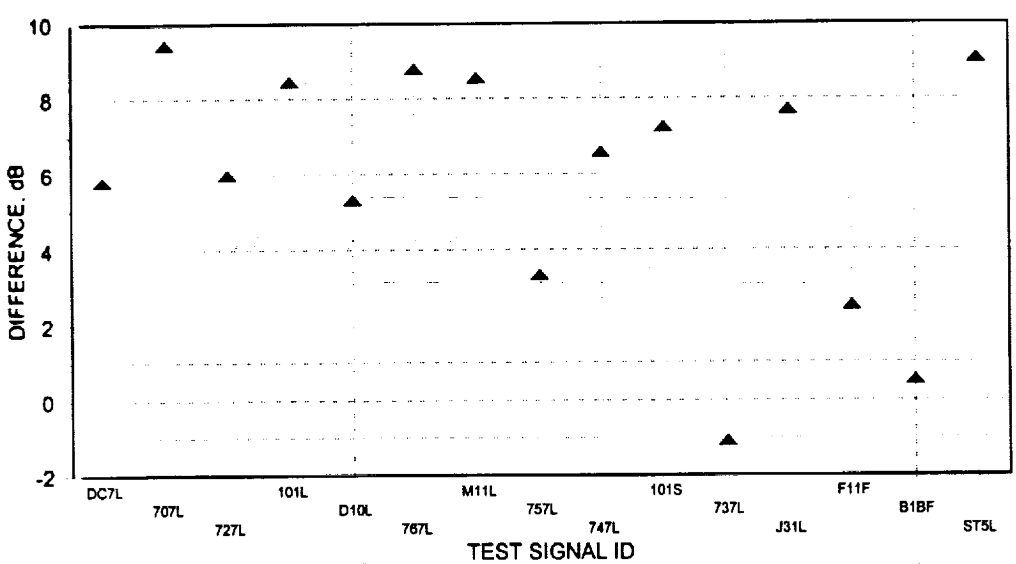

Figure 20 Results for landings in terms of differences in MXMA of the pairs of signals when SIMT is judged equally annoying to the test signal (SIMT - test signal).

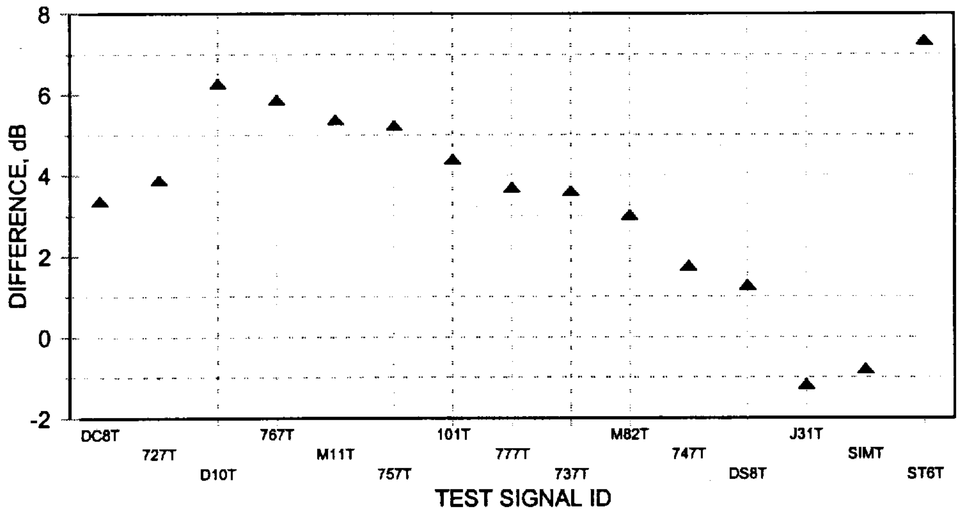

Figure 21 Results for takeoffs in terms of differences in EPNL of the pairs of signals when SIMT is judged equally annoying to the test signal (SIMT - test signal).

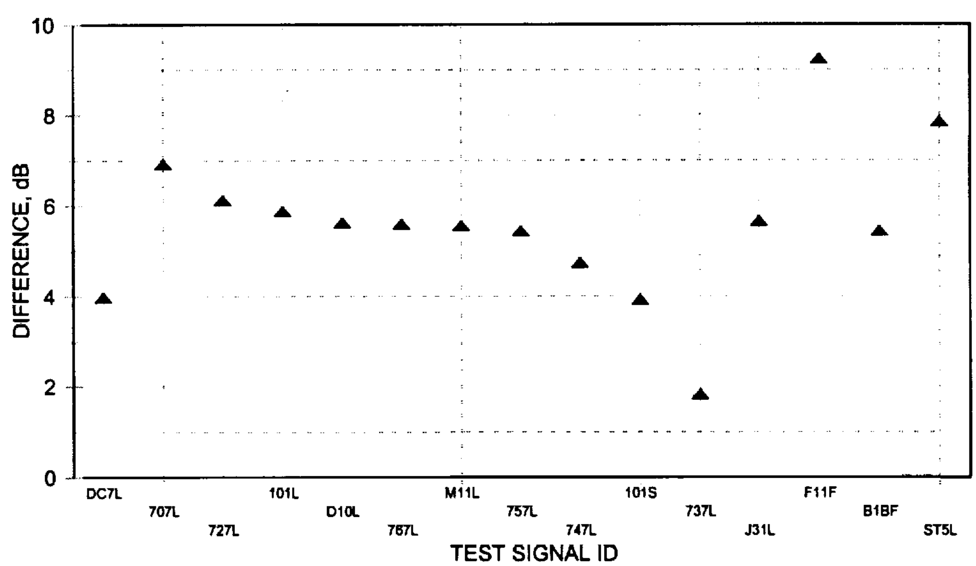

Figure 22 Results for landings in terms of differences in EPNL of the pairs of signals when SIMT is judged equally annoying to the test signal (SIMT - test signal).

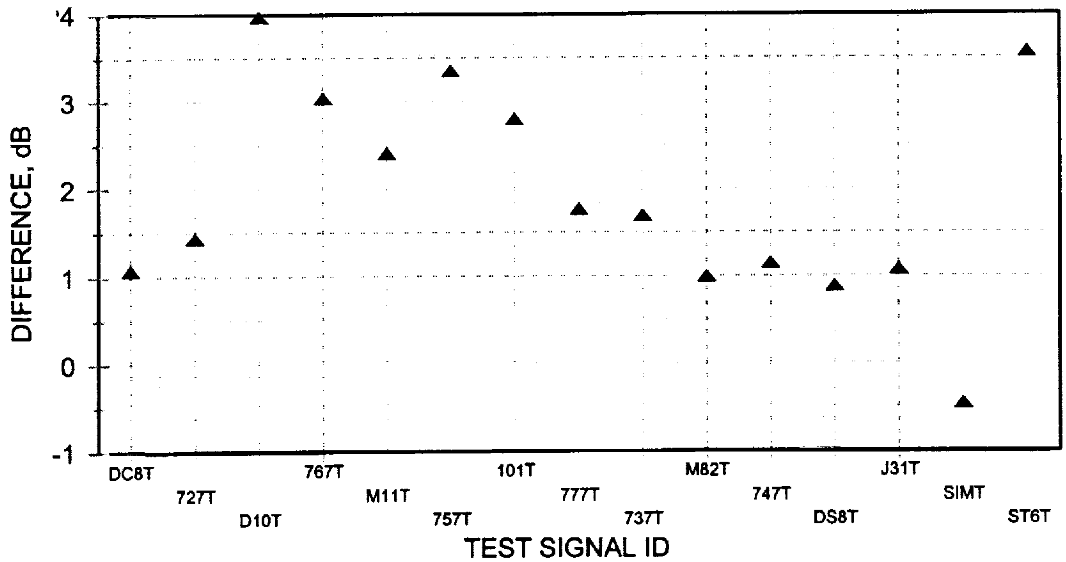

Figure 23 Results for takeoffs in terms of differences in LLZSEL of the pairs of signals when SIMT is judged equally annoying to the test signal (SIMT - test signal).

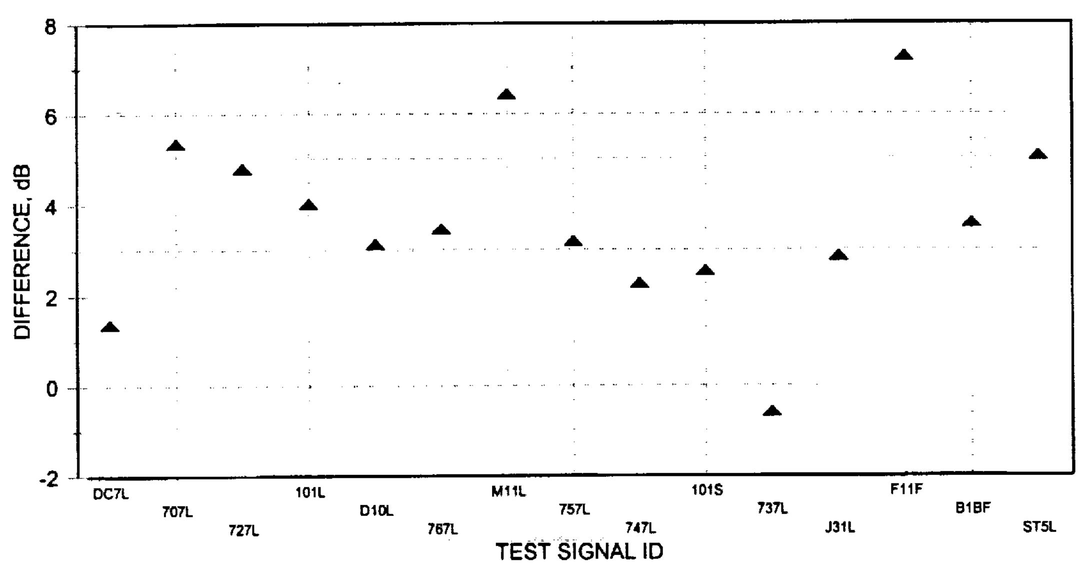

Figure 24 Results for landings in terms of differences in LLZSEL of the pairs of signals when SIMT is judged equally annoying to the test signal (SIMT - test signal).

4.4.3 Comparison with Prior Findings

Figures 25 and 26 compare averaged judgments of subjective equality of annoyance of overflights as heard indoors (measured by Pearsons *et al.*, 1996) with those of the current test. Figure 25 compares findings when the 727 takeoff (727T) served as the variable signal, while Figure 26 compares findings when the simulated takeoff (SIMT) served as the variable signal. If no difference had been observed between annoyance judgments for signals presented as heard indoors and outdoors, all of the points would have fallen along the angle bisector in all of these figures.

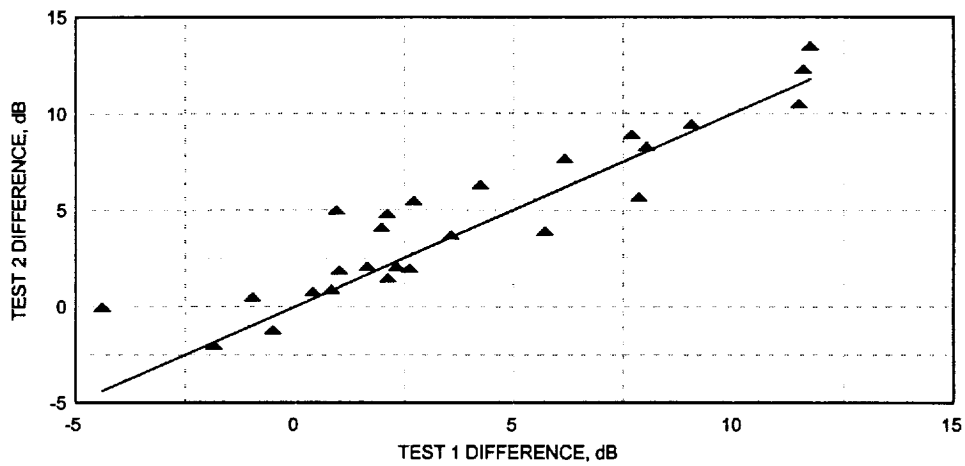

Figure 25 Comparison of Test 2 (outdoor) results with Test 1 (indoor) results using 727T as the variable signal.

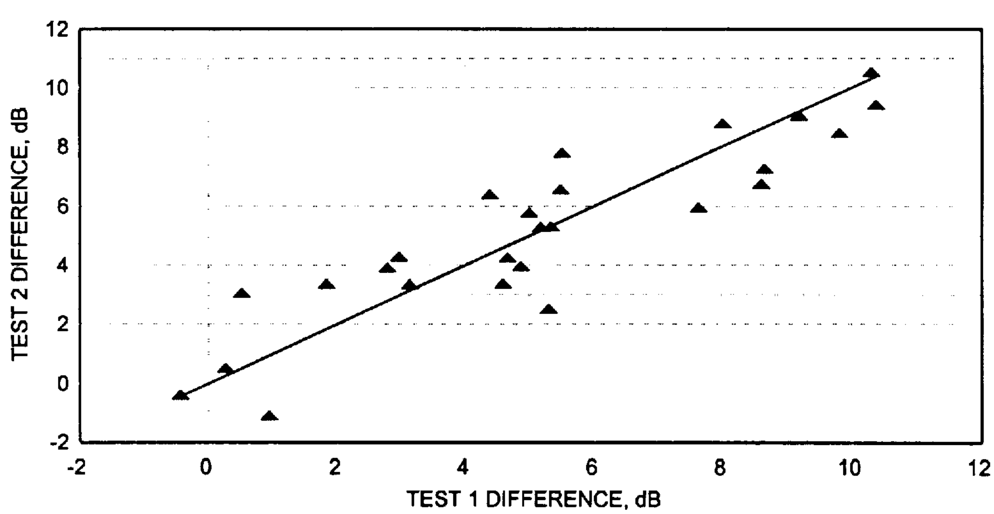

Figure 26 Comparison of Test 2 (outdoor) results with Test 1 (indoor) results using SIMT as the variable signal.

5 DISCUSSION

5.1 PERFORMANCE OF CLASSES OF NOISE METRICS AS PREDICTORS OF ANNOYANCE JUDGMENTS

Noise metrics that accord relatively little emphasis to low frequency energy generally behaved comparably as predictors of the judged annoyance of the aircraft noise test signals. As shown in Figures 6 through 8, metrics that accorded relatively greater emphasis to low frequency energy (B, C, and Flat or Overall) were less effective as predictors of annoyance judgments. These means and standard deviations are in agreement with those observed by Pearsons *et al.* (1996). As in the prior study, the figures also show that metrics based on Zwicker's Loudness Level predicted annoyance judgments with smaller offsets and standard deviations than less complex metrics. Metrics sensitive to signal duration afforded slightly improved performance as predictors of annoyance, even though the range in duration of test signals was small (10-20 seconds).

Although the range of 2 to 6 dB in standard deviations across test signals was as expected for the "better metrics" shown in Figures 6 through 8, the mean differences of 2 to 8 dB between signals judged equally annoying was unanticipated. It is apparent for these reasons that this offset is not an artifact of the estimation algorithm itself:

(1) test participants were able to come within 1 dB of matching the annoyance of test signals to themselves;
(2) repetition of test participants' average results were typically within 1 dB of the initial results; and
(3) the offset from 0 dB was notably smaller for an SEL-like variant of Zwicker's Loudness Level metric than for the remainder of the metrics.

The slight superiority of the Zwicker metrics as predictors of annoyance does not appear to be artifactual.

5.2 DIFFERENCES IN ANNOYANCE AMONG SETS OF TEST SIGNALS

Indications of systematic under or over-prediction of annoyance among sets of similar types of signals are noteworthy. For example, a comparison of the findings for the three noise metrics shown in Figures 11 through 17 and Figures 19 through 24 suggests that annoyance of takeoff noise is more accurately predicted by the three metrics than the annoyance of landing noise. This effect is particularly evident in comparisons against the recorded B-727 takeoff.

The test signals that simulated future aircraft takeoffs and landings produced results quite different from most of the other test signals. EPNL differences of 8-10 dB were observed in these comparisons, suggesting that EPNL considerably underestimates the annoyance of such artificial signals. However, EPNL also underestimated the annoyance of a 707 landing by 8-10 dB. Underestimates of the annoyance of the same test signal were also noted for other noise metrics.

Results for the commuter aircraft test signals (DS8T, J31T, and J31L) were comparable to the results for the Stage III aircraft. The differences in EPNL at judged equal annoyance were generally smaller than for most of the Stage III aircraft results except for the comparison of SIMT and J31L. Differences were no greater than the larger differences exhibited by the Stage III aircraft results.

A mixed 2 x 2 x 3 between-within-within subjects ANOVA was performed on mean PSE for annoyance to compare the results for Stage III aircraft with those of earlier Stage I and Stage II aircraft. The factors evaluated were type of aircraft (Stage III *vs.* Stages I and II), type of standard stimulus against which the comparison was made (727T *vs.* SIMT), and metric (EPNL, MXMA, and LLZSEL). Each case was a single aircraft, with responses averaged over all 30 subjects. All assumptions of the analysis were met, except heterogeneity of covariance for the metric error term. Because application of the Huynh-Feldt adjustments did not substantively affect the findings, the unadjusted results are reported. Table 6 presents the results of the analysis.

Table 6 Summary of results of ANOVA performed on mean point of subjective equality for annoyance.

SOURCE	SS	df	MS	F	PROBABILITY	PARTIAL η^2
BETWEEN AIRCRAFT						
Aircraft Type	0.01	1	<0.01	<0.01	0.98	
Error: Aircraft Type	554.01	19	29.16			
WITHIN AIRCRAFT						
Metric	61.37	2	30.69	16.61	<0.01	0.47
Metric by Aircraft Type	0.42	2	0.21	0.11	0.89	
Error: Metric	70.22	38	1.85			
Standard	6.59	1	6.59	1.42	0.25	
Standard by Aircraft Type	0.16	1	0.16	0.03	0.86	
Metric by Standard	17.33	2	8.67	351.53	<0.01	0.95
Metric by Standard by Aircraft Type	<0.01	2	<0.01	0.72	0.50	
Error: Metric by Standard	0.94	38	<0.01			

No evidence of an effect of aircraft type was found in this analysis. Differences between Stage III and Stages I or II aircraft did not appear, nor did aircraft type interact with type of metric or the stimulus chosen as standard.

The only reliable effects found were associated with metric. The main effect of metric was statistically significant, $F(1, 38) = 16.61, p < 0.01$. In general, PSEs were highest for MXMA (mean = 4.85) and EPNL (mean = 3.95), and were lowest for LLZSEL (mean = 2.84), the least biased metric. However, the pattern differed for the two standard stimuli, $F(2, 38) = 351.63, p < 0.01$, as seen in Figure 27, where data are averaged over aircraft type. Little difference between PSEs was observed for EPNL and LLZSEL when 727T served as the standard signal, but LLZSEL produced much smaller (less biased) PSEs than did EPNL when simulated aircraft noise was used as the standard signal.

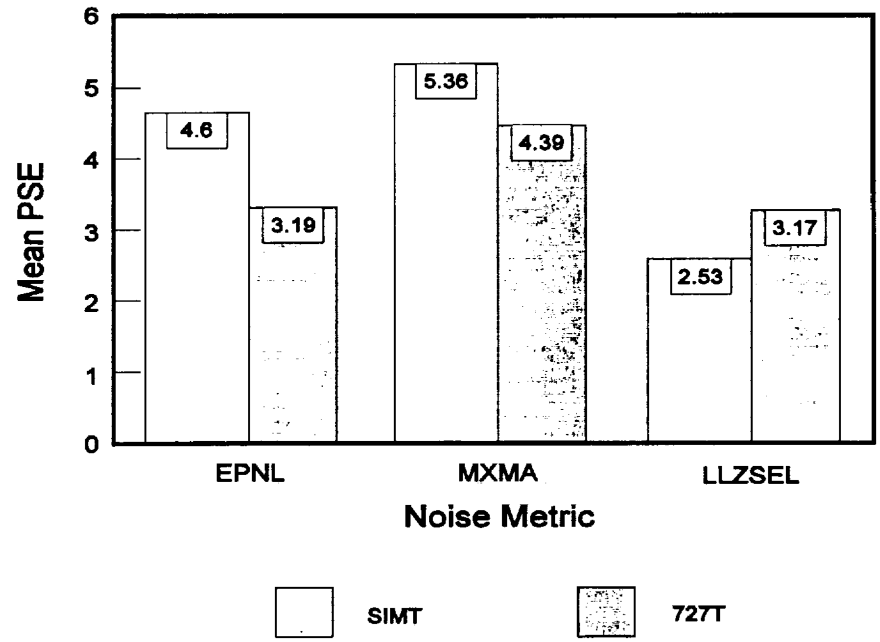

Figure 27 Mean difference in PSE (in dB) for annoyance for three metrics and two standard stimuli.

5.3 COMPARISON OF CURRENT RESULTS WITH THOSE OF PRIOR TEST

Even though higher signal presentation levels (characteristic of outdoor listening) were employed in the current study, the pattern of findings closely resembles that of Pearsons *et al.* (1996). A direct comparison of the indoor and outdoor results in terms of the difference in levels at the points of equal annoyance for those test signals that were used in both tests is nonetheless of interest. Figures 25 and 26 show such comparisons. The line in the figures represents complete agreement in the results of the two tests. The fact that the points lie on both sides of the line indicate a lack of systematic differences int he two studies. In general, agreement is within 5-8 dB.

Figure 28 plots grand mean differences of the current study and of Pearsons *et al.* (1996) for determinations of the points of subjective equality between both variable signals (B-727 takeoff and the simulated aircraft takeoff) and all fixed test signals (on the ordinate) against noise metrics (on the abscissa).

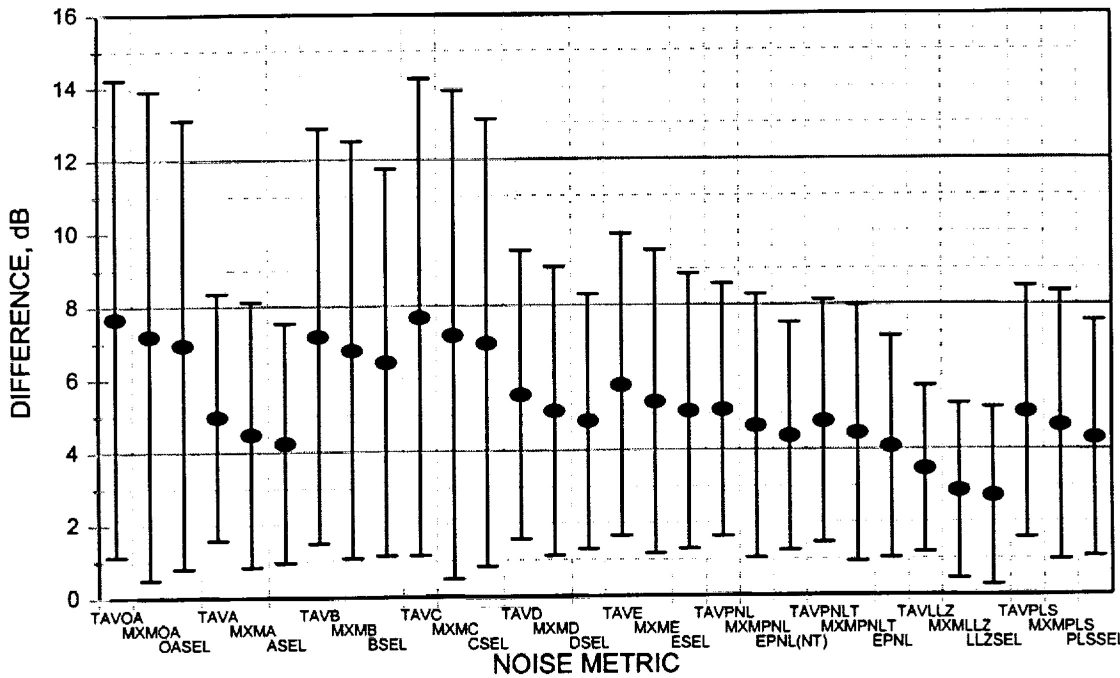

Figure 28 Average difference (±1 standard deviation) in noise metric of all test signals when judged equally annoying to both 727T and SIMT [(727T - test signal) and (SIMT - test signal)] for combined Pearsons *et al.* (1996) and current study.

5.4 RELATIONSHIPS AMONG NOISE METRICS

Table 7 is a matrix of product-moment correlations among all noise metrics at the signal levels corresponding to points of subjective equality of annoyance for all determinations made both by Pearsons *et al.* (1996) and in the current study.[2] As is typical for a set of signals with reasonably similar spectra, correlations among noise metrics are uniformly high. Although the number of cases was marginal, a principal components analysis of the correlation matrix was undertaken to determine the factorability of the correlation matrix, and the number of factors that might plausibly be extracted. All of the bivariate correlations were significantly different from zero; in fact, none was smaller than 0.70. The principal components analysis yielded a two factor solution.

Principal factors extraction with varimax rotation was then performed to produce a two factor solution accounting for 91% of the variance in the relationships among noise metrics. One of the factors, on which metrics such as B- and C-weighted SEL and time average metrics (as well as several others) loaded highly, seemed to reflect sensitivity to low frequency energy. The other factor, on which metrics such as maximum A-, D- and PNL metrics loaded highly (among others)

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[2] Fixed signal levels from both studies were adjusted to create signal levels corresponding to points of subjective equality of annoyance that were equal to the average of the variable 727 signal used in the current study.

seemed to reflect lesser sensitivity to low frequency energy. The SEL variant of the Zwicker metrics was not as closely associated with either of the dimensions as those noted above.

These findings should not be over-interpreted, since the correlations among noise metrics are dependent in part on the similarity of spectral shapes of the test signals presented for subjective judgment. However, it is clear from the information in Table 7 that a much smaller sub-set of noise metrics would suffice for most purposes in further studies of the annoyance of sets of aircraft flyovers.

5.5 IMPLICATIONS OF FINDINGS

A duration-adjusted variant of Zwicker's Loudness Level was observed to offer minor improvements in accuracy and precision over EPNL as a predictor of the annoyance of aircraft noise. Averaged over all comparisons, the difference between fixed and variable test signals was 4.0 dB for EPNL, but only 3.2 dB for LLZSEL. Further, the standard deviation for EPNL was 3.0 dB, but only 2.4 dB for LLZSEL. In other words, EPNL underestimates the annoyance of the test signals (most of which were produced by Stage III aircraft) by 4.0 dB, while LLZSEL underestimates the annoyance of these aircraft by only 3.2 dB.

The overall pattern of findings thus suggest that while EPNL may not be the single most effective predictor of the annoyance of aircraft overflights, no other of the tested metrics offers more than a marginal improvement in accuracy or precision of prediction. It also seems unlikely that any other relatively simple noise metric that could be devised would improve greatly upon the performance of available noise metrics.

Other findings, such as the apparent underestimation of the annoyance of landing with respect to takeoff noise, and the underestimation of the annoyance of noise from simulated future aircraft takeoffs and landings, may merit further investigation, since the metric used to certify noise from aircraft overflights should accurately predict the annoyance of both takeoff and landing noise, regardless of engine type. As noted above, however, the correlations among noise metrics are so high that it is doubtful that a further study of the annoyance of recorded flyover noises alone could provide enough experimental leverage to draw any finer distinctions among their ability to predict annoyance. Any further study of this nature should be based on judgments of the annoyance of synthetic signals created analytically to minimize correlations among the noise metrics of principal interest.

Table 7 Correlations of all metric pairs for (adjusted) fixed signals at the point of subjective equality of annoyance in combined studies.

	ASEL	BSEL	CSEL	DSEL	EPNL	EPNLNT	ESEL	LLZSEL	MXMA	MXMB	MXMC	MXMD	MXME	MXMLLZ	MXMOA	MXMPLS	MXMPNL	MXMPNLT	OASEL	PLSSEL	TAVA	TAVB	TAVC	TAVD	TAVE	TAVLLZ	TAVOA	TAVPLS	TAVPNL	TAVPNLT
ASEL	1.00																													
BSEL	0.92	1.00																												
CSEL	0.84	0.98	1.00																											
DSEL	0.91	0.92	0.88	1.00																										
EPNL	0.89	0.90	0.88	0.97	1.00																									
EPNLNT	0.91	0.91	0.88	0.99	0.99	1.00																								
ESEL	0.94	0.96	0.93	0.98	0.96	0.97	1.00																							
LLZSEL	0.90	0.86	0.81	0.87	0.88	0.90	0.88	1.00																						
MXMA	0.88	0.80	0.75	0.77	0.78	0.78	0.83	0.72	1.00																					
MXMB	0.87	0.95	0.94	0.85	0.85	0.85	0.91	0.79	0.90	1.00																				
MXMC	0.81	0.94	0.96	0.84	0.84	0.84	0.89	0.77	0.82	0.99	1.00																			
MXMD	0.82	0.82	0.80	0.89	0.88	0.88	0.88	0.74	0.90	0.90	0.87	1.00																		
MXME	0.88	0.88	0.86	0.88	0.87	0.88	0.91	0.77	0.95	0.96	0.92	0.98	1.00																	
MXMLLZ	0.76	0.71	0.69	0.71	0.75	0.76	0.74	0.83	0.86	0.82	0.78	0.84	0.86	1.00																
MXMOA	0.81	0.94	0.96	0.84	0.84	0.84	0.89	0.77	0.82	0.98	1.00	0.87	0.92	0.78	1.00															
MXMPLS	0.84	0.85	0.83	0.83	0.85	0.85	0.87	0.80	0.93	0.94	0.91	0.96	0.98	0.92	0.91	1.00														
MXMPNL	0.81	0.80	0.79	0.86	0.88	0.88	0.85	0.76	0.90	0.89	0.86	0.98	0.97	0.89	0.87	0.97	1.00													
MXMPNLT	0.79	0.78	0.77	0.83	0.87	0.85	0.83	0.74	0.89	0.88	0.85	0.96	0.95	0.87	0.85	0.95	0.98	1.00												
OASEL	0.83	0.98	1.00	0.88	0.88	0.88	0.93	0.81	0.74	0.94	0.96	0.80	0.85	0.69	0.96	0.83	0.78	0.77	1.00											
PLSSEL	0.93	0.95	0.93	0.94	0.94	0.96	0.97	0.94	0.81	0.90	0.89	0.85	0.88	0.81	0.89	0.89	0.84	0.82	0.92	1.00										
TAVA	0.94	0.85	0.79	0.87	0.86	0.87	0.90	0.77	0.93	0.86	0.80	0.86	0.90	0.75	0.79	0.86	0.86	0.83	0.79	0.86	1.00									
TAVB	0.90	0.98	0.96	0.91	0.89	0.90	0.96	0.80	0.85	0.96	0.95	0.86	0.91	0.72	0.95	0.88	0.85	0.82	0.96	0.93	0.91	1.00								
TAVC	0.85	0.98	0.98	0.89	0.87	0.88	0.93	0.79	0.79	0.96	0.97	0.84	0.89	0.70	0.97	0.86	0.83	0.81	0.98	0.91	0.84	0.99	1.00							
TAVD	0.86	0.85	0.82	0.96	0.93	0.94	0.93	0.75	0.82	0.84	0.81	0.92	0.90	0.70	0.81	0.85	0.89	0.87	0.82	0.87	0.92	0.90	0.87	1.00						
TAVE	0.92	0.92	0.89	0.95	0.93	0.95	0.97	0.79	0.87	0.91	0.87	0.92	0.93	0.73	0.87	0.88	0.89	0.87	0.88	0.91	0.96	0.96	0.93	0.98	1.00					
TAVLLZ	0.89	0.84	0.81	0.87	0.90	0.92	0.89	0.91	0.84	0.84	0.81	0.85	0.86	0.88	0.81	0.89	0.88	0.85	0.81	0.91	0.91	0.87	0.83	0.88	0.90	1.00				
TAVOA	0.85	0.98	0.98	0.89	0.87	0.88	0.93	0.79	0.79	0.96	0.97	0.84	0.89	0.70	0.97	0.86	0.83	0.81	0.98	0.91	0.84	0.99	1.00	0.87	0.92	0.83	1.00			
TAVPLS	0.92	0.92	0.89	0.93	0.93	0.95	0.96	0.86	0.88	0.92	0.89	0.91	0.93	0.82	0.89	0.93	0.91	0.88	0.89	0.96	0.94	0.95	0.92	0.95	0.97	0.95	0.92	1.00		
TAVPNL	0.87	0.84	0.82	0.94	0.94	0.95	0.92	0.78	0.83	0.84	0.81	0.91	0.90	0.74	0.81	0.86	0.91	0.89	0.82	0.88	0.93	0.90	0.86	0.99	0.97	0.92	0.86	0.96	1.00	
TAVPNLT	0.86	0.84	0.81	0.93	0.96	0.95	0.92	0.77	0.83	0.84	0.82	0.91	0.90	0.73	0.82	0.86	0.91	0.91	0.81	0.87	0.91	0.89	0.86	0.98	0.96	0.90	0.86	0.94	0.99	1.00

6 CONCLUSIONS

The following observations may be made about the current data set of subjective judgments of the annoyance of aircraft overflight noise.

1. The relative performance of the various noise metrics as predictors of annoyance of Stage II and Stage III aircraft was indistinguishable.

2. Flat, C-weighted and B-weighted metrics afforded the least accurate and precise estimates of the annoyance of overflights.

3. A-, D-, and E-weighted metrics were of comparable accuracy as predictors of the annoyance of overflights.

4. Time-integrated metrics provided slightly more accurate and precise estimates of the annoyance of aircraft overflights than maximum level measures, although differences in test signal durations were minor.

5. A time-integrated variant of Zwicker's Loudness Level metric provided the most accurate and precise prediction of aircraft overflight annoyance.

6. The results of comparisons of test signals against a B-727 takeoff comparison were comparable to those observed in comparisons against a simulated aircraft takeoff, although the results using a simulated aircraft takeoff provided somewhat more discrimination among metrics.

7. The annoyance of simulations of takeoff and landing noise of future aircraft was most greatly under-predicted by all of the metrics under evaluation.

8. Good agreement between indoor and outdoor listening conditions suggested no systematic bias between the current study and that of Pearsons *et al.* (1996) in obtaining predictions of annoyance in either environment.

9. Small differences in average results between 12 and 20 trials suggested negligible benefit in administering the additional trials.

10. The annoyance of commuter aircraft noise was comparable to that of Stage III aircraft.

7 ACKNOWLEDGMENTS

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9 GLOSSARY

Acoustic terms in this Glossary are defined as by *American National Standard S1.1-1994 Acoustical Terminology*.

ANOVA. Analysis of variance.

C-weighted sound exposure level. Sound exposure level, as defined in Part 1, where C-weighted sound pressure is used instead of A-weighted sound pressure. Unit, decibel; abbreviation, CSEL, symbol, L_{CE}.

energy average. Colloquial term for time-mean-square average of a series of sound signals.

energy summation. Colloquial term loosely used to indicate addition of noncoherent sound signals by the sum of the squares of their sound pressures or sound exposures.

maximum sound level; maximum frequency-weighted sound pressure level. Greatest fast (125-ms) A-weighted sound level, within a stated time interval. Alternatively, slow (1000 ms) time-weighting and C frequency-weighting may be specified. Unit, decibel (dB); abbreviation, MXFA; symbol, L_{AFmx}. (or C and S).

perceived noise level. Frequency-weighted sound pressure level obtained by a stated procedure that combines the sound pressure levels in the 24 one-third octave bands with midband frequencies from 50 Hz to 10 kHz. Unit, decibel (dB); abbreviation, PNL; symbol, L_{PN}.

NOTE – Procedures for computing perceived noise level are stated in Federal Aviation Regulation Part 36, *Noise Standards: Aircraft Type and Airworthiness Certification*, Appendix B, and in International Civil Aviation Organization Annex 16, Volume 1, *Aircraft Noise*, Third Edition, July 1993.

PSE. Point of subjective equality (of annoyance judgments).

sound exposure. Time integral of squared, instantaneous frequency-weighted sound pressure over a stated time interval or event. Unit: pascal-squared second; symbol, E.

NOTES

1 If frequency weighting is not specified, A-frequency weighting is understood. If other than A- frequency weighting is used, such as C-frequency weighting, an appropriate subscript should be added to the symbol; i.e., E_C.

2 Duration of integration is implicitly included in the time integral and need not be reported explicitly. For the sound exposure measured over a specified time interval such as one hour, a 15-hour day, or a 9-hour night, the duration should be indicated by the abbreviation or letter symbol, for example one-hour sound exposure (1HSE or E_{1h}) for a particular hour; day sound exposure (DSE or E_d) from 0700 to 2200 hours; and night sound exposure (NSE or E_n) from 0000 to 0700 hours plus from 2200 to 2400 hours.

3 Day-night sound exposure (DNSE or E_{dn}) for a 24-hour day is the sum of the day sound exposure and ten times the night sound exposure.

4 Unless otherwise stated, the normal unit for sound exposure is the pascal-squared second.

sound exposure level. Ten times the logarithm to the base ten of the ratio of a given time integral of squared instantaneous A-weighted sound pressure, over a stated time interval or event, to the product of the squared reference sound pressure of 20 micropascals and reference duration of one second. The frequency weighting and reference sound exposure may be otherwise if stated explicitly. Unit, decibel (dB); abbreviation, SEL; symbol, L_{AE}.

NOTE - In symbols, (A-weighted) sound exposure level is:

$$L_{AE} = 10 \lg\{[\int_0^T p_A^2(t)\,dt\,]/p_0^2\,t_0\}$$

$$= 10 \lg(E/E_0)$$

$$= L_{AT} + 10 \lg(T/t_0)$$

where p_A^2 is the squared instantaneous A- weighted sound pressure, a function of time t; for gases $p_0 = 20\ \mu$Pa; $t_0 =$ 1 s; E is sound exposure; $E_0 = p_0^2 t_0 = (20\ \mu\text{Pa})^2$s is reference sound exposure.

sound level; weighted sound pressure level. Ten times the logarithm to the base ten of the ratio of A-weighted squared sound pressure to the squared reference sound pressure of 20 μPa, the squared sound pressure being obtained with fast (F) (125-ms) exponentially weighted time-averaging. Alternatively, slow (S) (1000-ms) exponentially weighted time-averaging may be specified; also C-frequency weighting. Unit, decibel (dB); symbol L_A, L_C.

NOTES

1 In symbols, A-weighted sound level $L_{A\tau}(t)$ at running time t is:

$$L_{A\tau}(t) = 10 \lg\{[(1/\tau) \int_{-\infty}^{t} p_A^2(\xi) e^{-(t-\xi)/\tau}\, d\xi\,] / p_0^2\}$$

where τ is the exponential time constant in seconds, ξ is a dummy variable of integration, $p_A^2(\xi)$ is the squared, instantaneous, time-varying, A-weighted sound pressure in pascals, and p_0 is the reference sound pressure of 20 μPa. Division by time constant τ yields the running time average of the exponential-time-weighted, squared sound-pressure signal. Initiation of the running time average from some time in the past is indicated by $-\infty$ for the beginning of the integral.

2 ANSI S1.4-1983, *American National Standard Specification for Sound Level Meters*, gives standard frequency weightings A and C and standard exponential time weightings fast (F) and slow (S).

sound pressure; effective sound pressure. Root-mean-square instantaneous sound pressure at a point, during a given time interval. Unit, pascal (Pa).

NOTE - In the case of periodic sound pressures, the interval is an integral number of periods or an interval that is long compared to a period. In the case of non-periodic sound pressures, the interval should be long enough to make the measured sound pressure essentially independent of small changes in the duration of the interval.

sound pressure level. (a) Ten times the logarithm to the base ten of the ratio of the time-mean-square pressure of a sound, in a stated frequency band, to the square of the reference sound pressure in gases of 20 μPa. Unit, decibel (dB); abbreviation, SEL; symbol, L_p.

time-average sound level; time-interval equivalent continuous sound level; time-interval equivalent continuous A-weighted sound pressure level; equivalent continuous sound level. Ten times the logarithm to the base ten of the ratio of time-mean-square instantaneous A-weighted sound pressure, during a stated time interval T, to the square of the standard reference sound pressure. Unit, decibel (dB); respective abbreviations, TAV and TEQ; respective symbols, L_{AT} and L_{AeqT}.

NOTES

1 A frequency weighting other than the standard A-weighting may be employed if specified explicitly. The frequency weighting that is essentially constant between limits specified by a manufacturer is called flat.

2 In symbols, time-average (time-interval equivalent continuous) A-weighted sound level in decibels is:

$$L_{AT} = 10 \lg\{[(1/T)\int_0^T p_A^2(t)\mathrm{d}t]/p_0^2\}$$

$$= L_{AeqT}$$

where p_A^2 is the squared instantaneous A-weighted sound pressure signal, a function of elapsed time t; in gases reference sound pressure p_0 = 20 μPa; T is a stated time interval.

3 In principle, the sound pressure signal is not exponentially time-weighted, either before or after squaring.

APPENDIX A Instructions and Consent Form for Test Participants

1 Instructions to Test Participants

Your basic job will be to listen carefully to pairs of sounds that you will hear while seated in a special sound room, and to decide right after hearing each pair of sounds whether the first or the second of the sounds was the more annoying to you. Each pair of sounds is a "trial." Several dozen trials will be heard in each "session." You will have a rest break between each session, during which you should leave the sound room for five minutes.

A computer will select the pairs of sounds that you will hear, and record your decisions about which of the pair was the more annoying. The computer needs information about who you are, when to start playing the sounds, and so forth. This information will be entered by the experimenter just prior to each session.

1.2 Beginning the Experiment

Once you have moved into the room where the experiment will take place, sit down in the chair facing the speaker and computer screen. You will find a computer "mouse" on a pad on the armrest of the chair. You will use this mouse to tell the computer when to play sounds and which of a pair of sounds is the more annoying.

The screen will ask you "Are you ready to begin Experiment..." As soon as you are comfortably seated and ready to start, move the mouse arrow to the "Yes" box and click the left mouse button once. This will start the test session.

You will be asked to judge the annoyance of several different pairs of sounds during each test session. Your job will always be to listen carefully to each sound in each pair, and to judge the noisiness of the sounds as you would if you heard them in your home twenty to thirty times a day. After the second sound of each pair ends, you will then be asked which of the two was the more annoying. The presentation of each pair of signals will look like this on the screen:

1. The screen will say "Experiment in Progress" and "Listen now for sound [1]." The computer will play the first sound.

2. Then the screen will say "Listen now for sound [2]" and the computer will play the second sound.

3. Once the second sound has finished playing the screen will say "Which sound was more annoying?" and you will see two blue rectangles on the screen: one that says "First" and another that says "Second." Use the mouse to position the arrow over the first or second rectangle to tell the computer which sound you felt was more annoying. Then press the left mouse button. You will hear the next pair of sounds shortly after you press the left mouse button.

Each test session will last approximately 25 minutes, after which you should stand up, leave the sound room, and take a five minute break. You will be expected to finish four such sessions each day that you take part in this study, for a total of 2 hours per day.

When a test session is over, the computer will present a small box that says "You have finished Experiment ..." and an OK button. Click the OK button using the left mouse button, as soon as you are ready to continue. If there are more sessions scheduled for the day, a window will appear asking if you are ready to begin. Don't press the "Yes" button until you come back from your break and are ready to continue. Press the "Yes" button to continue with the next session after you are sitting down and are comfortable again.

If you have completed your four sessions for the day, answer "No" to the "Are You Ready for Experiment..." question.

1.3 Additional Information

If you feel uncomfortable in the sound room at any time, you may simply stand up, open the door and leave the room.

If the computer screen asks you to get the experimenter at any time during the session, you should stand up, open the door, and find the experimenter.

CONSENT FORM FOR AIRCRAFT NOISE ANNOYANCE STUDY

BBN Systems and Technologies (BBN) is conducting a laboratory study of the annoyance of the noise of certain aircraft flyovers, and would like you to take part in this research project. This form explains what is expected of people who wish to take part in this study. Please sign this form at the bottom after you have read it if you would like to take part in this study.

I understand that I will be asked to listen attentively to pairs of aircraft overflights, each lasting as long as 30 seconds, and to indicate which of the pair of sounds is the more annoying. Since the aircraft overflights will be heard at levels typical of airport communities, some may be uncomfortably loud. My participation in this test will not, however, pose any meaningful risk of hearing damage.

I understand that I will be given an audiogram prior to the start of my participation in these listening tests, and upon completion of testing. No other audiometric or medical services will be provided in connection with this testing.

All listening will be done in an anechoic chamber. Each testing session will last approximately two hours, with five minute breaks (during which I will leave the anechoic chamber) provided every half hour. I will also be free to leave the anechoic chamber at any time that I wish. I further understand that I may change my mind about taking part in this study at any time. If I decide to stop taking part in the study, I will be paid for the amount of time that I did take part.

I will be expected to take part in several such listening sessions, and will be paid at a daily rate of $20.00 for each day of testing.

I certify that I am 18 years of age or older, that I have read the information on this page, and that I want to take part in this study of aircraft noise annoyance.

Signed ____________________ Print Name ________________________

Date ____________________ Phone No. ________________________

APPENDIX B Spectra of Test Signals at Maximum A-Level for Comparison with Boeing 727 Takeoff and Simulated Takeoff Test Signals

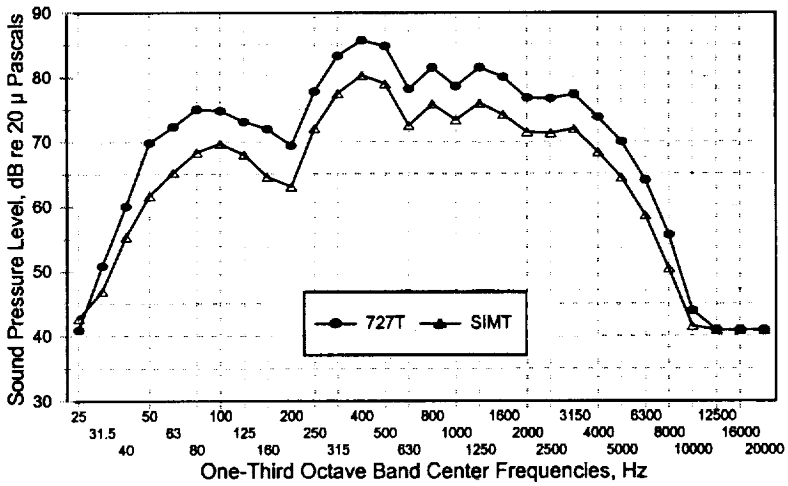

Figure 29 Test signal 1 — Lockheed L1011 landing (101L) presentation levels.

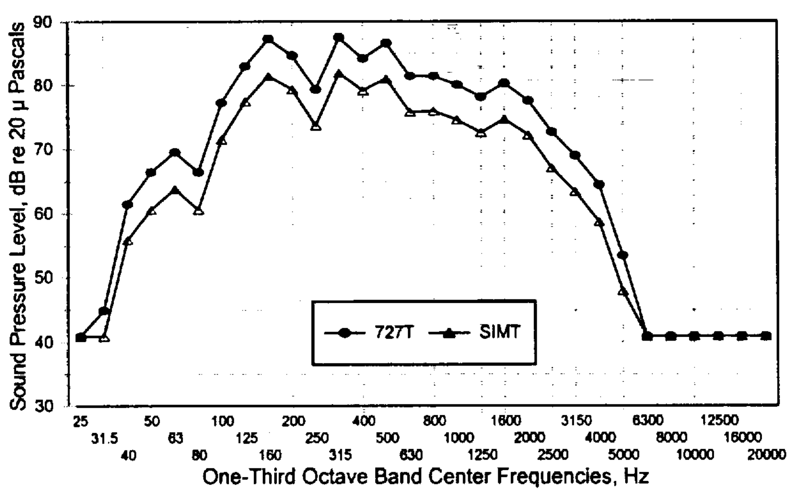

Figure 30 Test signal 2 — Lockheed L1011 takeoff (101L) presentation levels.

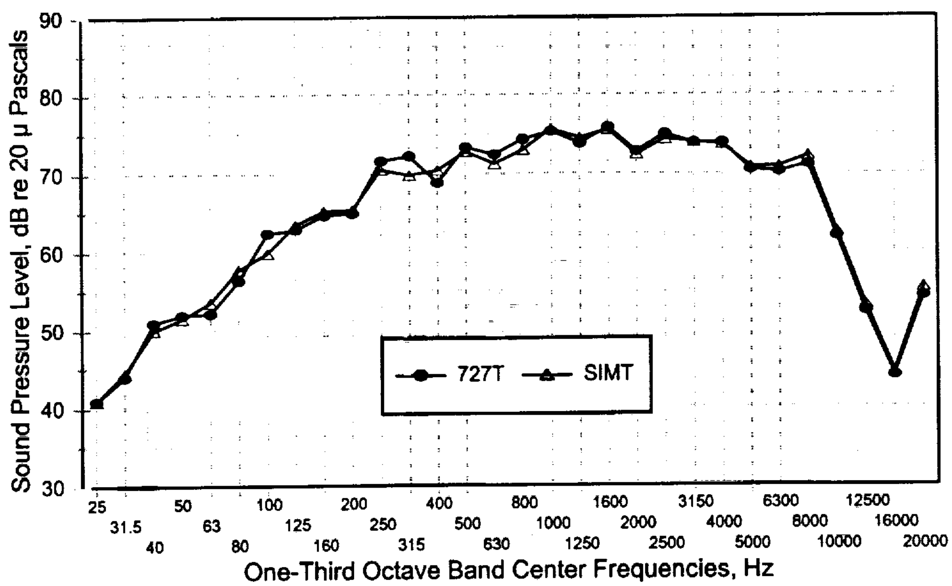

Figure 31 Test signal 3 — Boeing 707 landing (707L) presentation levels.

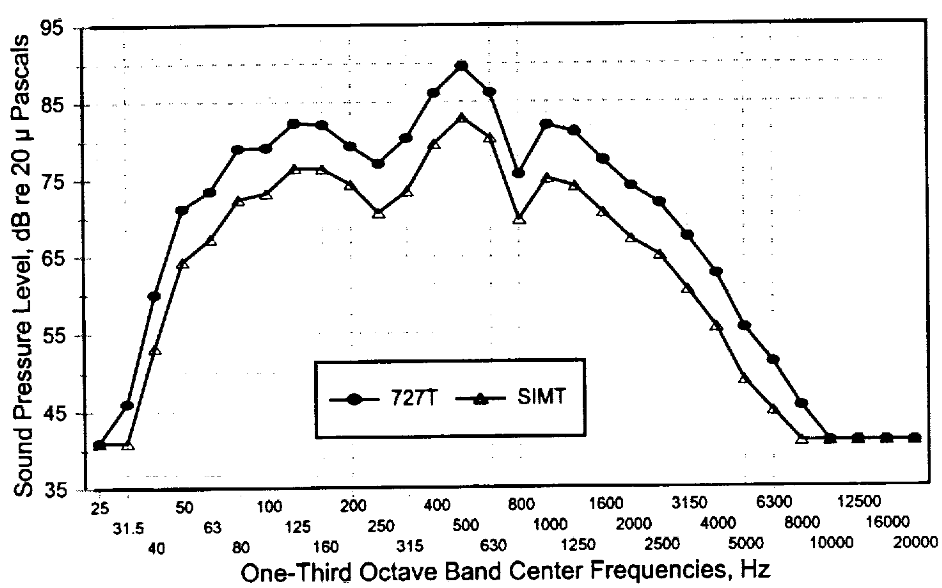

Figure 32 Test signal 4 — Boeing 727 landing (727L) presentation levels.

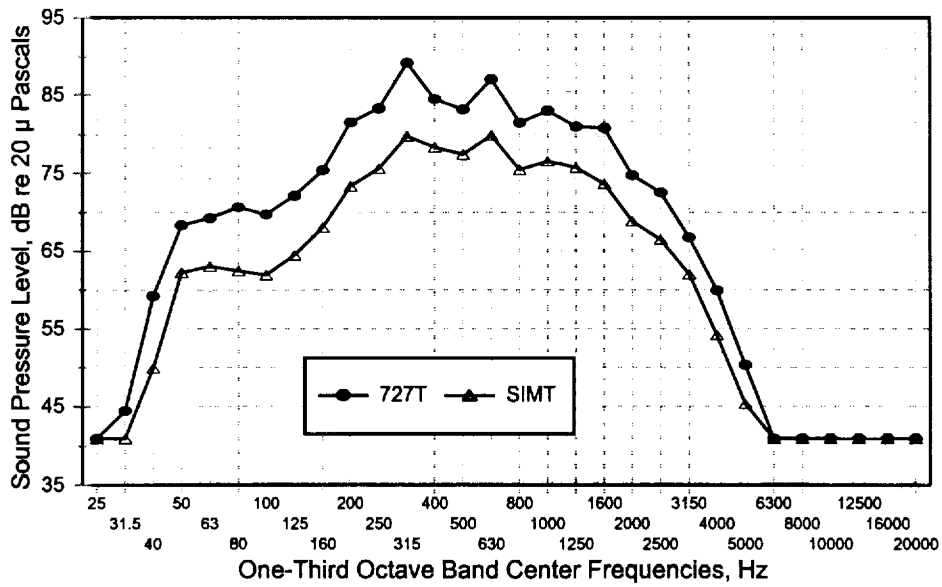

Figure 33 Test signal 5 — Boeing 727 takeoff (727T) presentation levels.

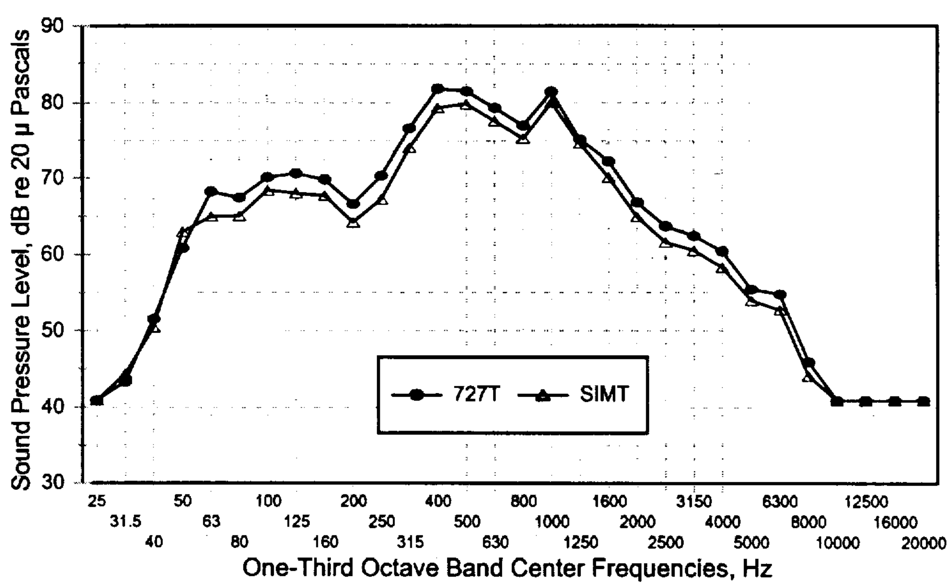

Figure 34 Test signal 6 — Boeing 737 landing (737L) presentation levels.

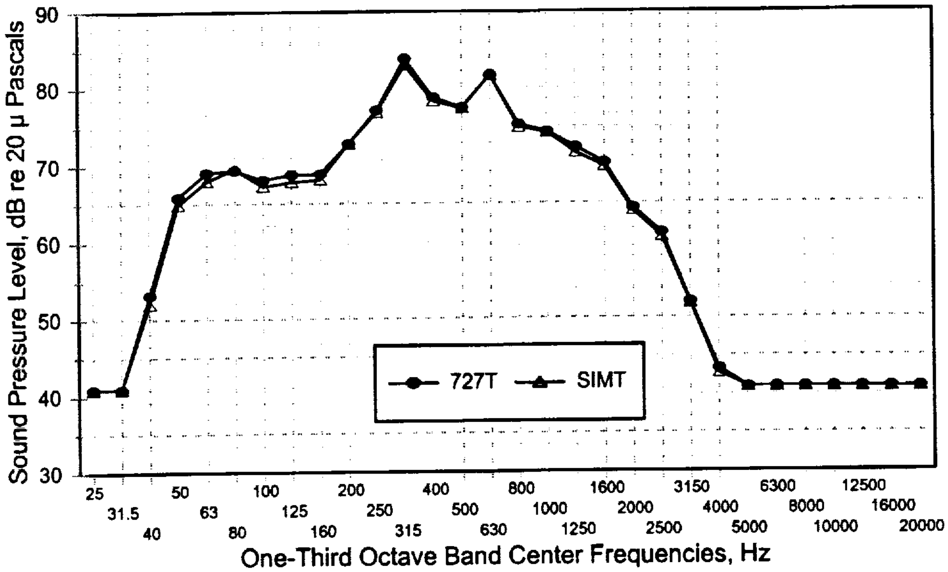

Figure 35 Test signal 7 — Boeing 737 takeoff (737T) presentation levels.

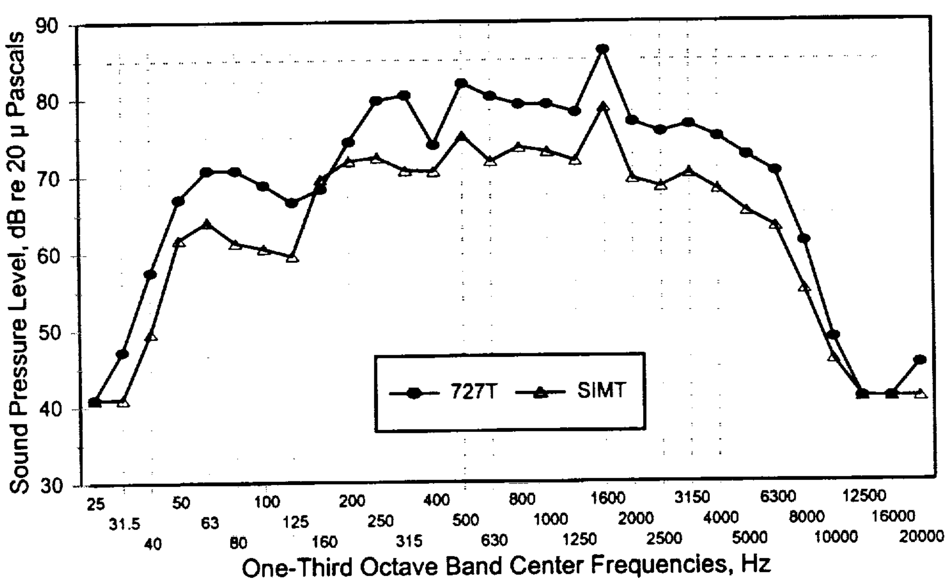

Figure 36 Test signal 8 — Boeing 747 landing (747L) presentation levels.

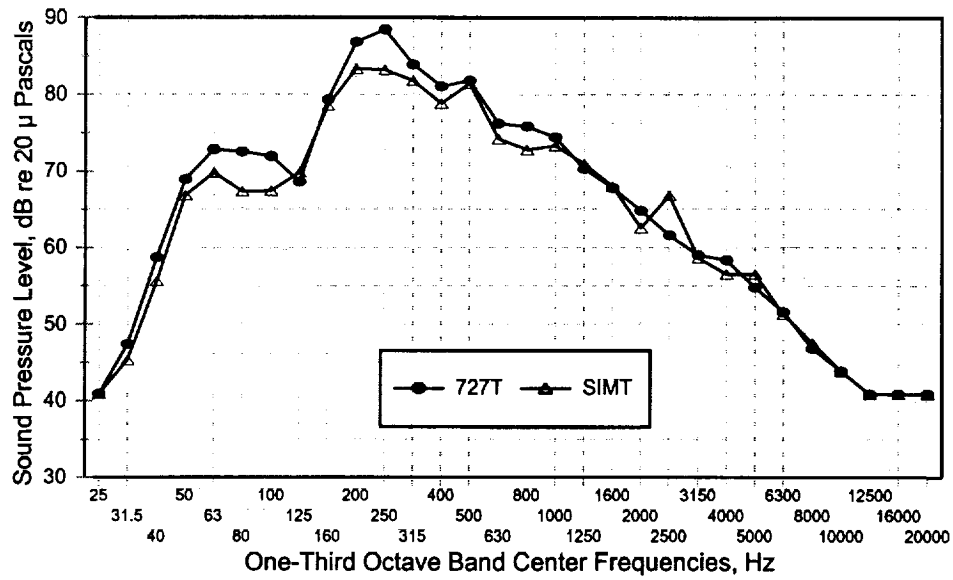

Figure 37 Test signal 9 — Boeing 747 takeoff (747T) presentation levels.

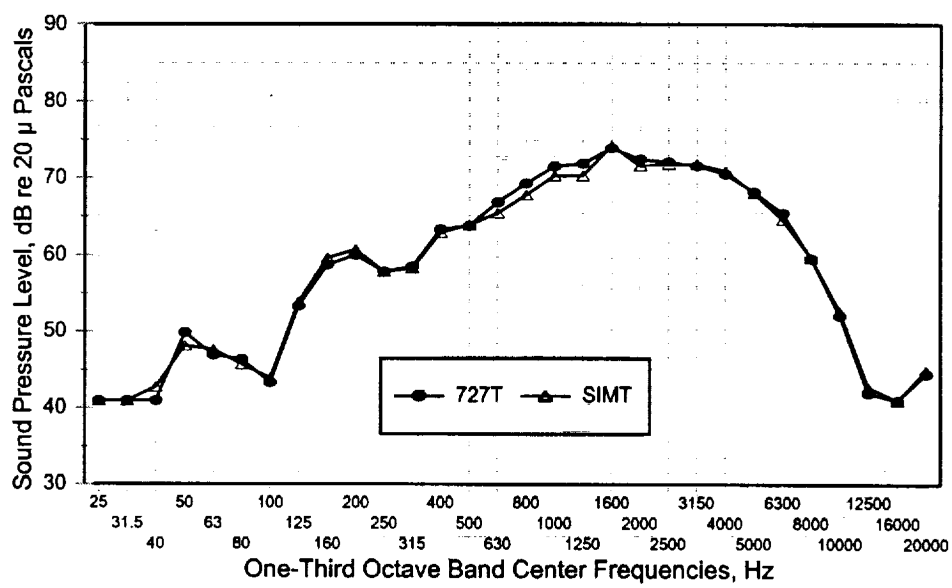

Figure 38 Test signal 10 — Boeing 757 landing (757L) presentation levels.

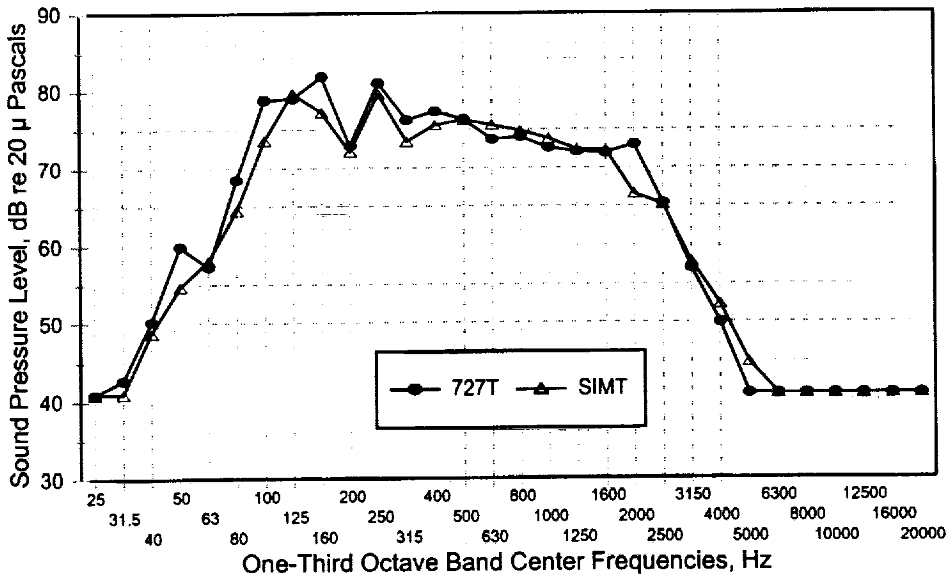

Figure 39 Test signal 11 — Boeing 757 takeoff (757T) presentation levels.

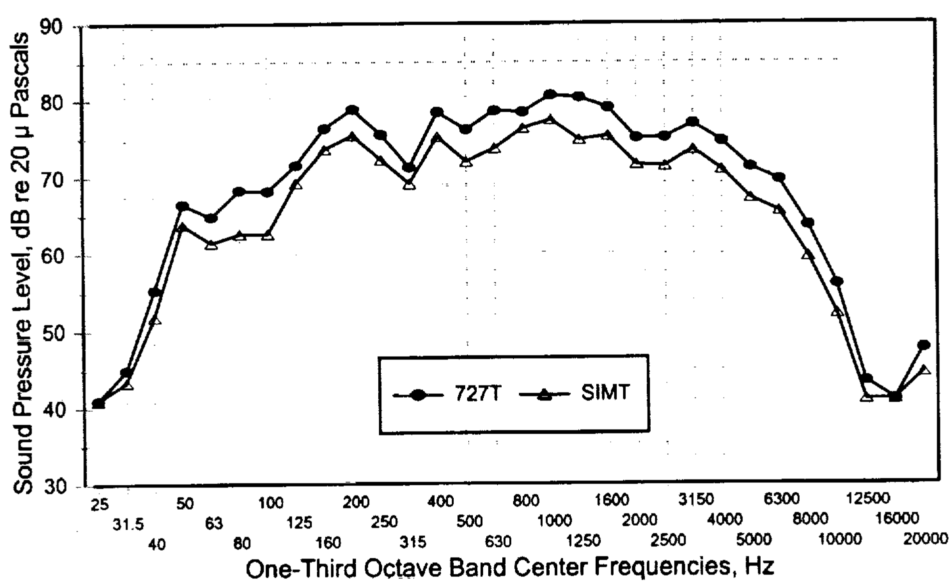

Figure 40 Test signal 12 — Boeing 767 landing (767L) presentation levels.

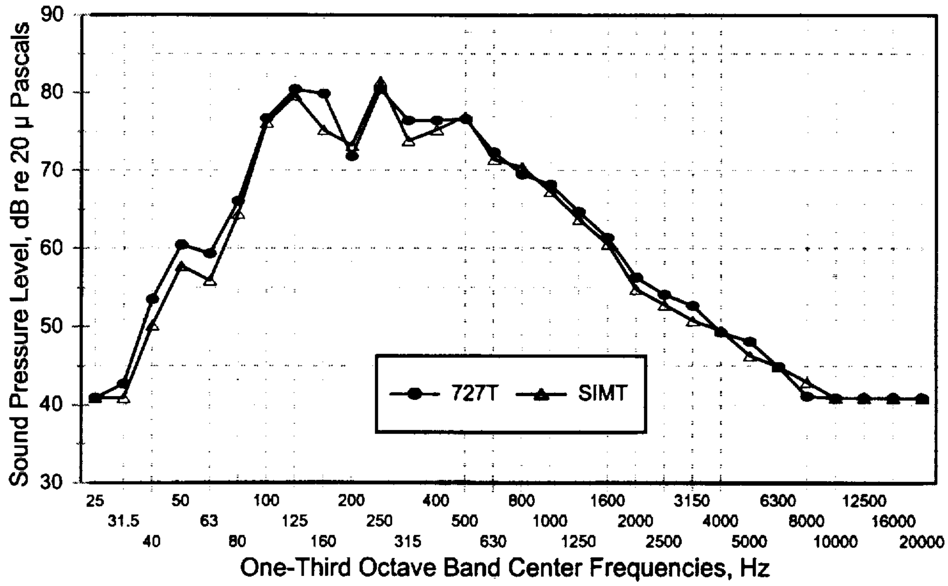

Figure 41 Test signal 13 — Boeing 767 takeoff (767T) presentation levels.

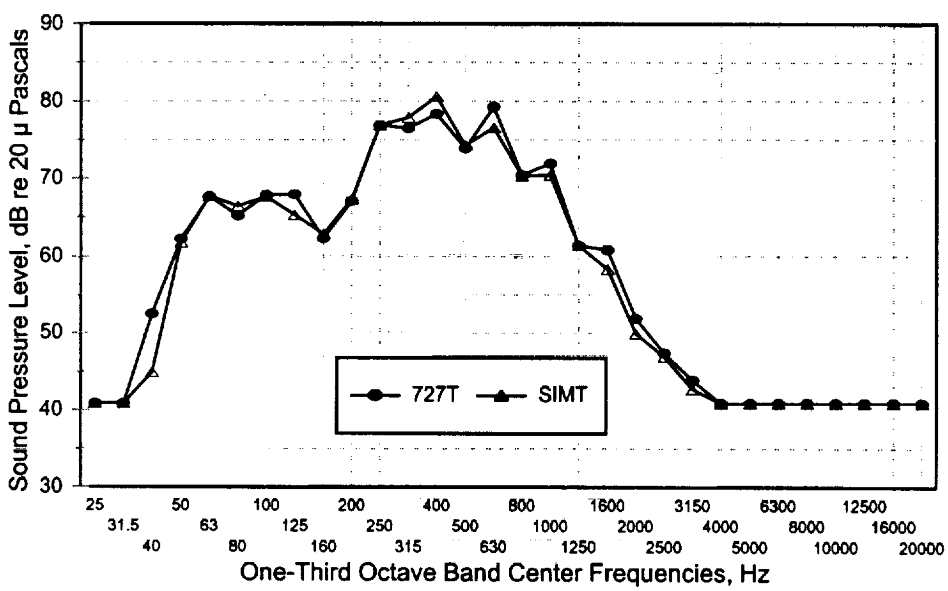

Figure 42 Test signal 14 — Boeing 777 takeoff (777T) presentation levels.

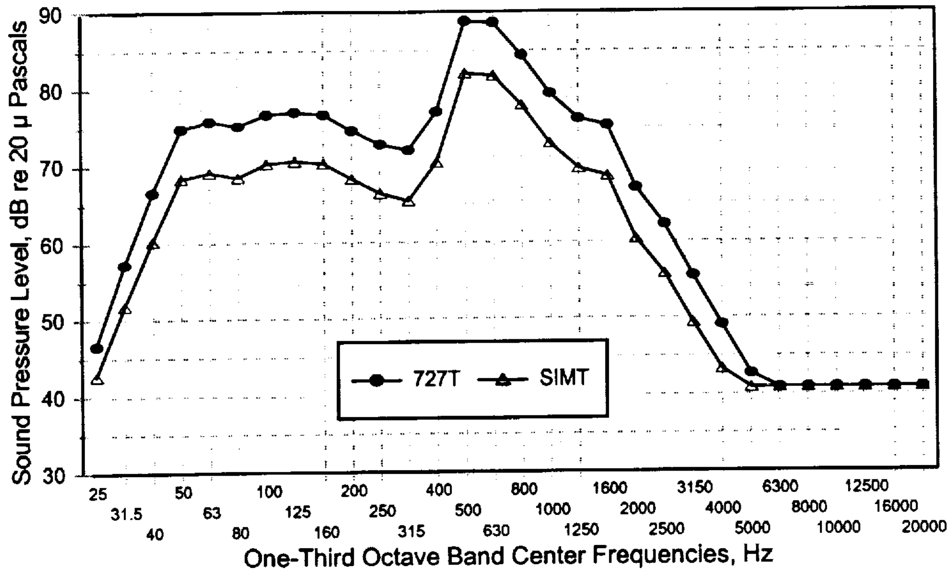

Figure 43 Test signal 15 — B1 bomber flyover (B1BF) presentation levels.

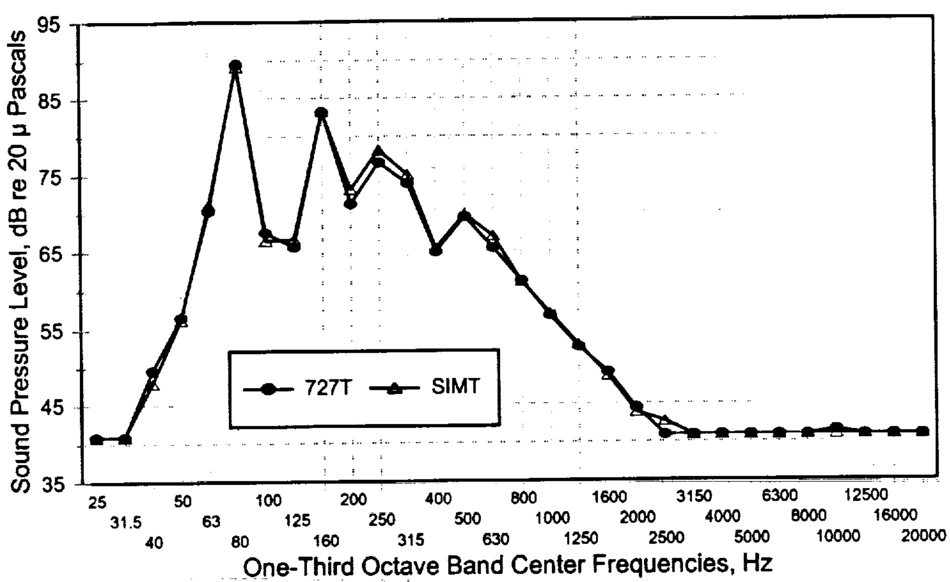

Figure 44 Test signal 16 — De Havilland Dash 8 takeoff (DS8T) presentation levels.

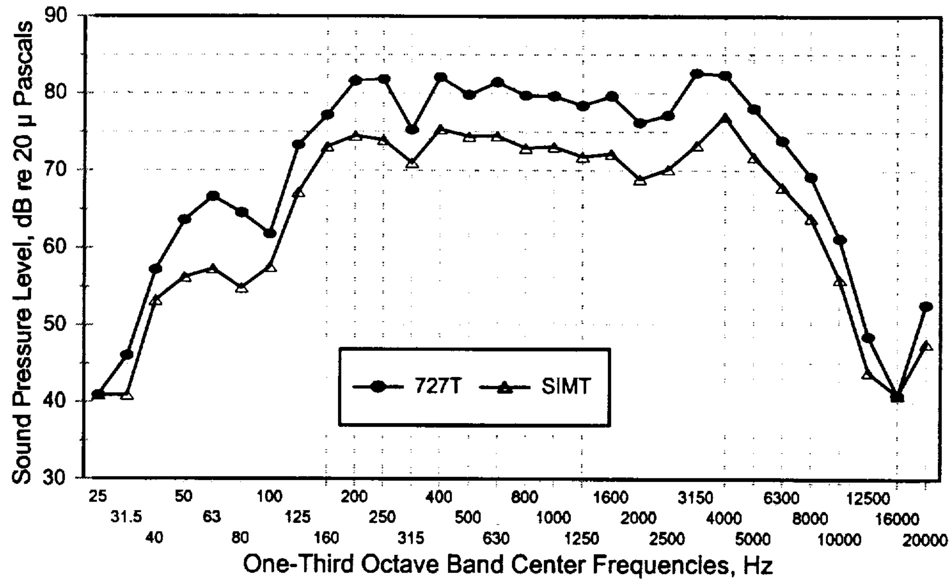

Figure 45 Test signal 17 — McDonnell Douglas DC10 landing (D10L) presentation levels.

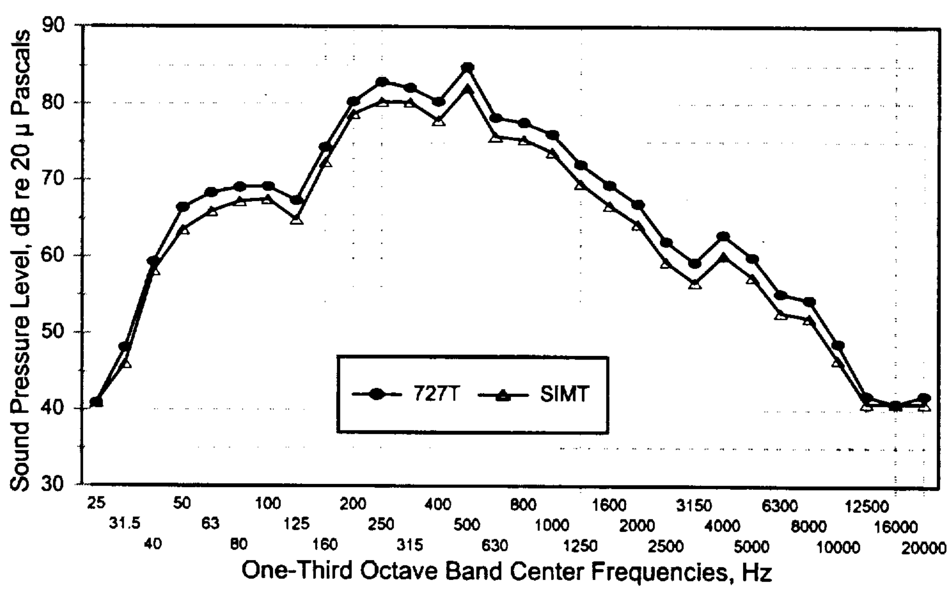

Figure 46 Test signal 18 — McDonnell Douglas DC10 takeoff (D10T) presentation levels.

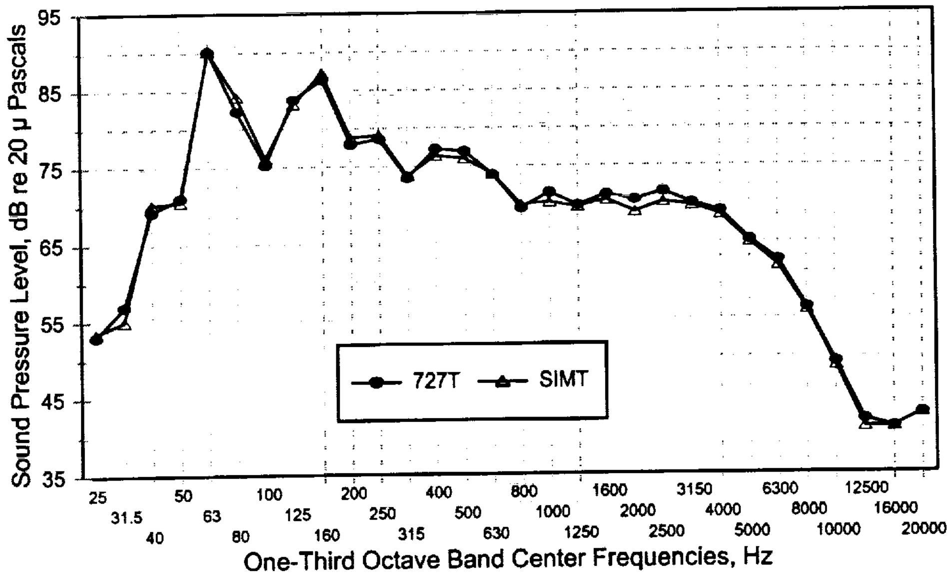

Figure 47 Test signal 19 — Douglas Corporation DC7 landing (DC7L) presentation levels.

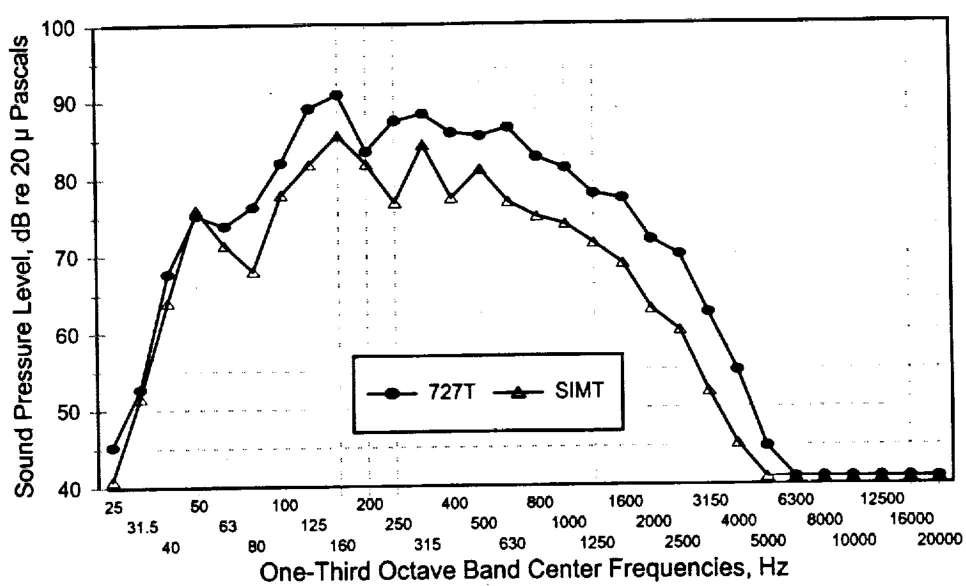

Figure 48 Test signal 20 — Douglas Corporation DC8 takeoff (DC8T) presentation levels.

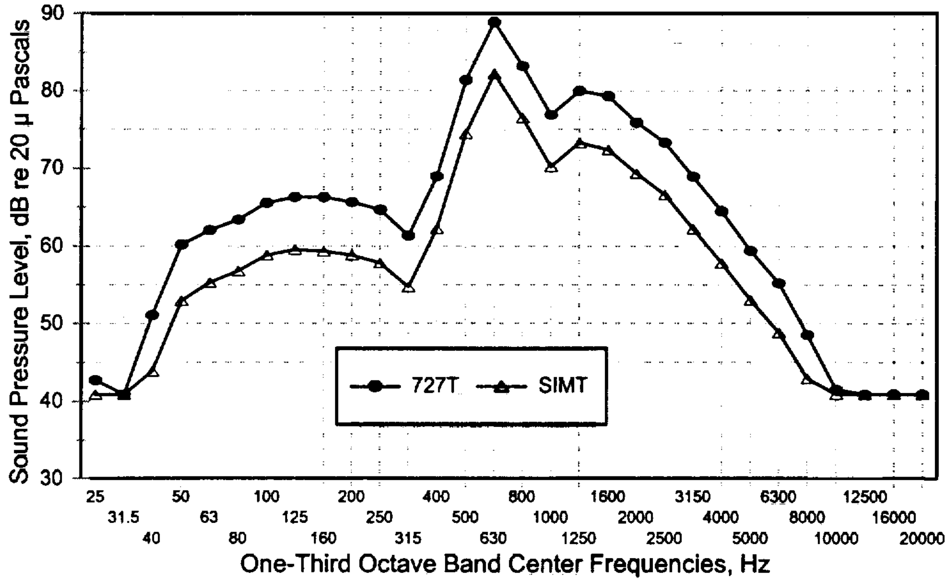

Figure 49 Test signal 21 — F111 flyover (F11F) presentation levels.

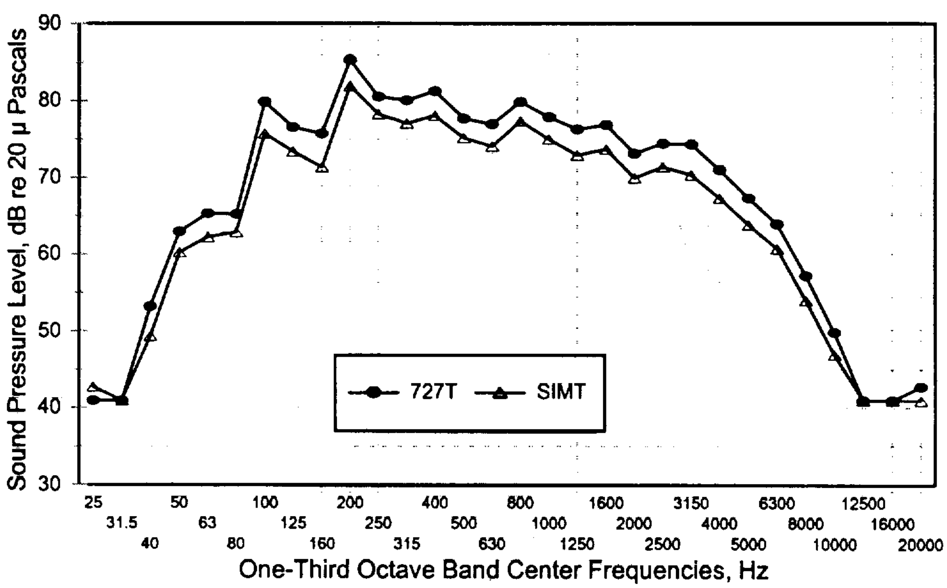

Figure 50 Test signal 22 — Jetstream 31 landing (J31L) presentation levels.

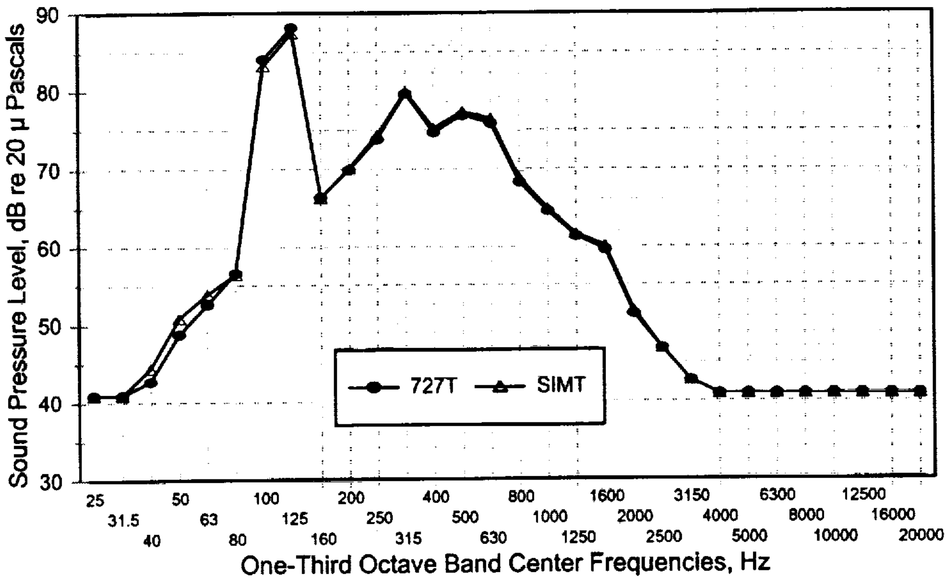

Figure 51 Test signal 23 — Jetstream 31 takeoff (J31T) presentation levels.

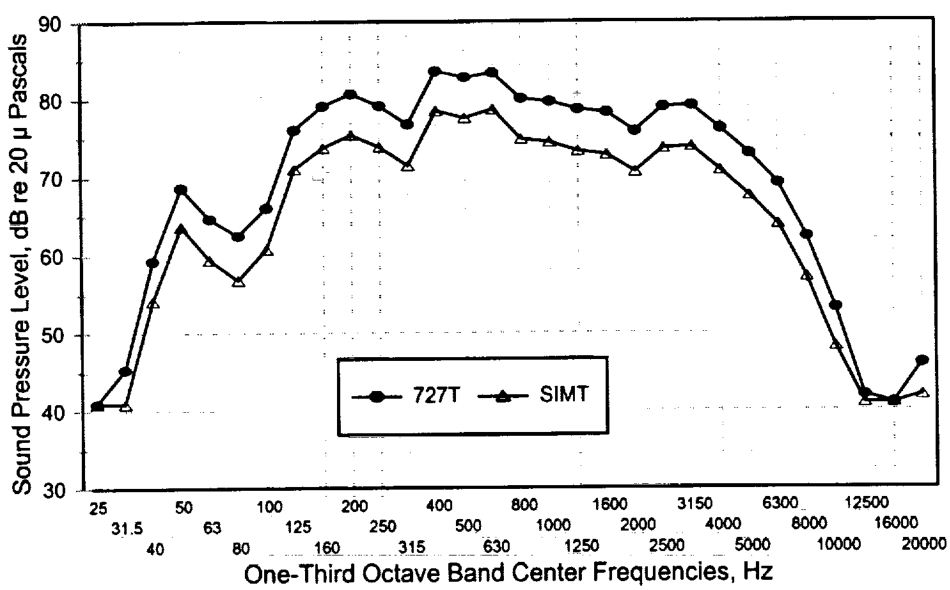

Figure 52 Test signal 24 — McDonnell Douglas MD11 landing (M11L) presentation levels.

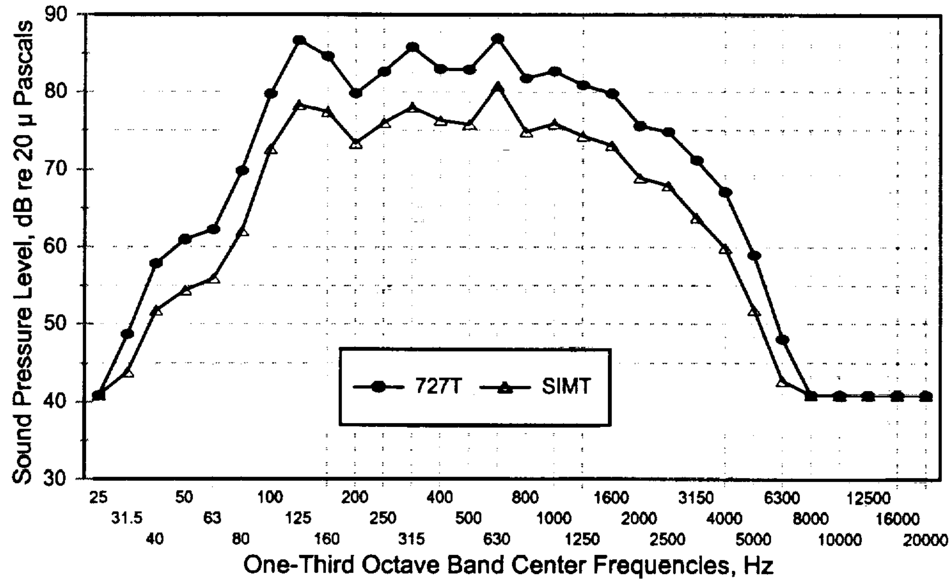

Figure 53 Test signal 25 — McDonnell Douglas MD11 takeoff (M11T) presentation levels.

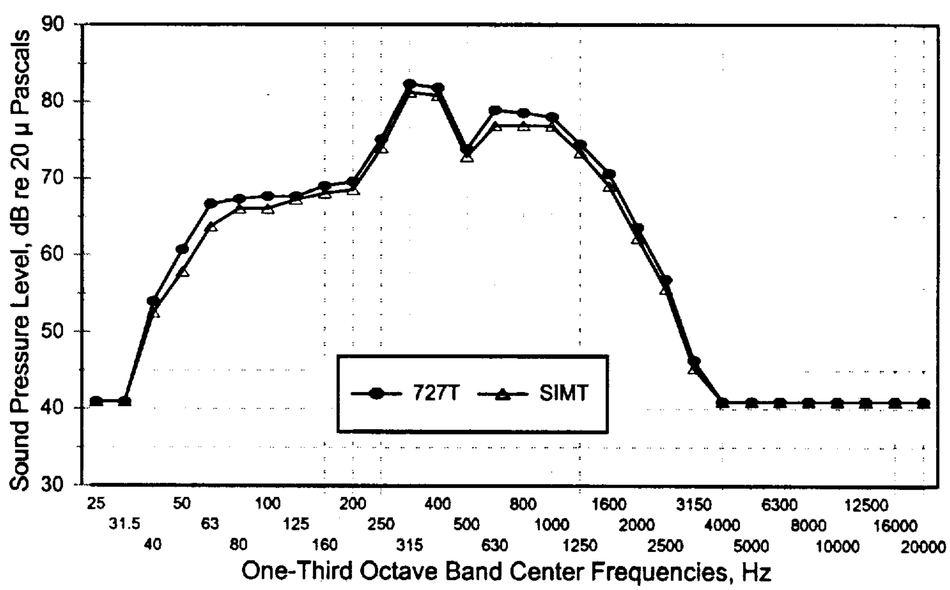

Figure 54 Test signal 26 — McDonnell Douglas MD82 takeoff (M82T) presentation levels.

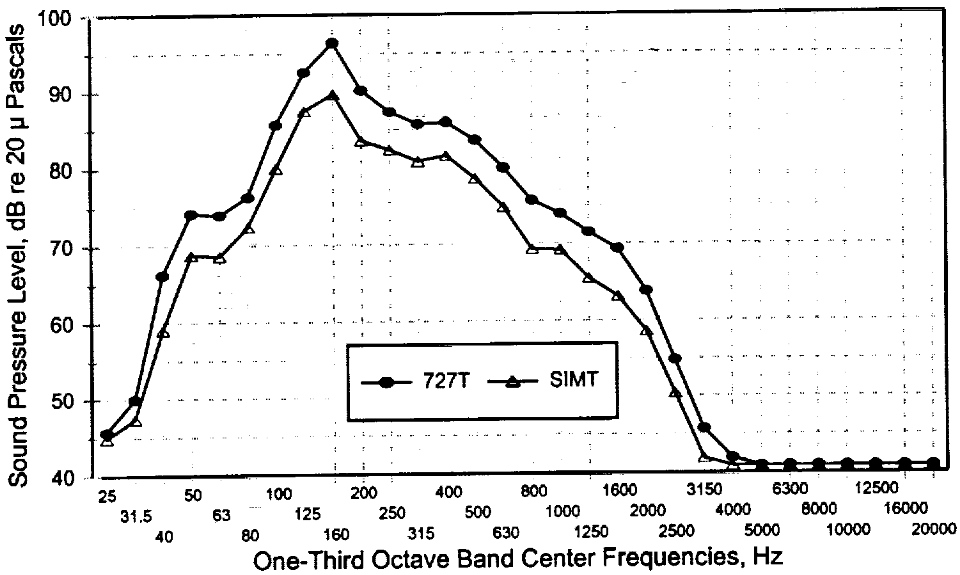

Figure 55 Test signal 27 — simulated takeoff (SIMT) presentation levels (short duration).

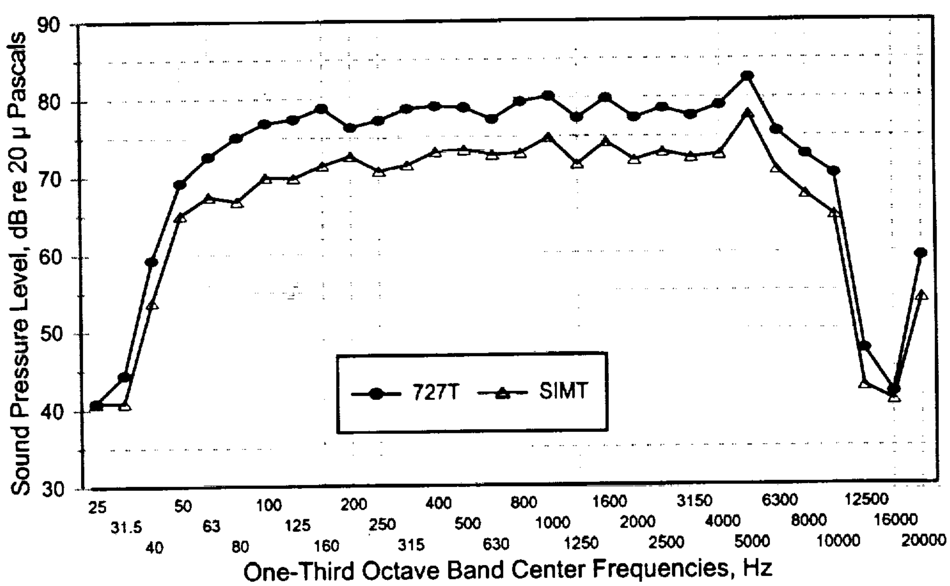

Figure 56 Test signal 28 — simulated Stage X aircraft landing (ST5L) presentation levels.

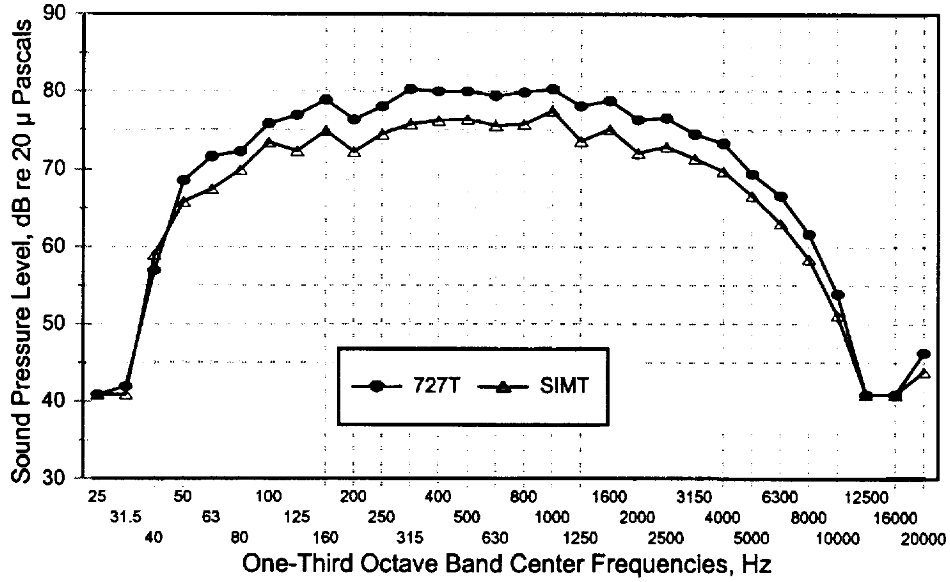

Figure 57 Test signal 29 — simulated Stage X aircraft takeoff (ST6T) presentation levels.

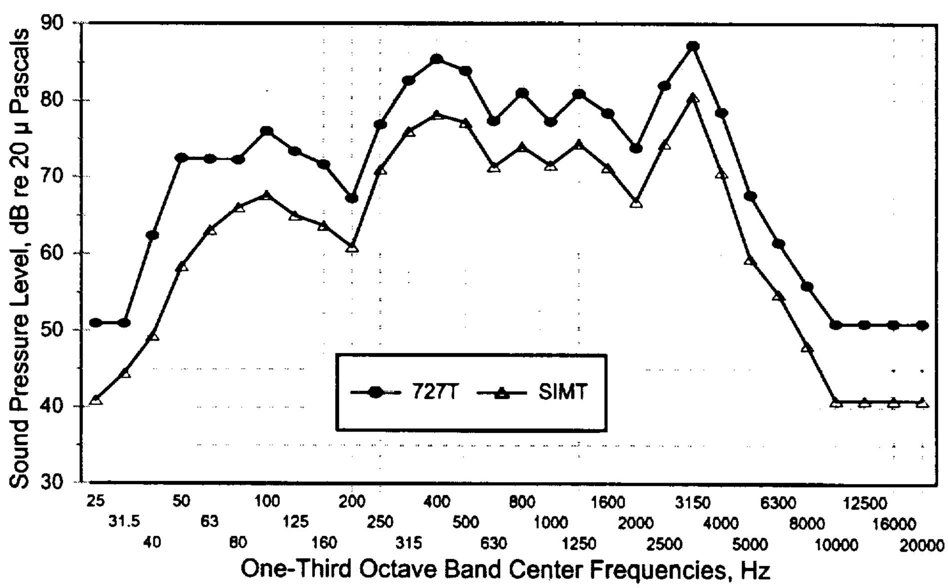

Figure 58 Test signal 30 — Lockheed L1011 landing (101S) presentation levels (spectrum modified to accentuate tone).

Table 8 One-third octave band levels of test signals at time of maximum A-level for comparison with Boeing 727 takeoff test signal.

1/3 OB (Hz)	TEST SIGNAL IDENTIFICATION NUMBER														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
25	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	46.6
31.5	50.8	44.9	43.9	46	44.4	43.3	40.9	47.2	47.4	40.9	42.7	44.9	42.7	40.9	57.2
40	60	61.5	50.9	60	59.2	51.5	53.2	57.5	58.7	40.9	50.2	55.3	53.5	52.5	66.6
50	69.8	66.4	51.9	71.2	68.3	60.8	65.9	67	68.9	49.8	59.9	66.5	60.4	62.2	74.9
63	72.3	69.5	52.1	73.5	69.2	68.2	69.1	70.7	72.8	46.9	57.3	64.8	59.3	67.6	75.8
80	75	66.4	56.3	79	70.6	67.4	69.4	70.7	72.5	46.3	68.5	68.3	66.1	65.2	75.2
100	74.8	77.2	62.3	79.1	69.7	70.1	68.2	68.8	71.9	43.3	78.8	68.2	76.7	67.8	76.7
125	73.1	83	62.8	82.3	72.1	70.6	68.8	66.6	68.6	53.3	79	71.5	80.4	67.9	77
160	72	87.3	64.6	82.1	75.4	69.8	68.9	68.3	79.3	58.7	81.8	76.3	79.8	62.3	76.7
200	69.4	84.7	64.9	79.3	81.5	66.6	72.8	74.3	86.8	60	72.9	78.8	71.8	67.1	74.6
250	77.8	79.3	71.6	77	83.3	70.3	77.2	79.7	88.5	57.8	81	75.5	80.4	76.9	72.8
315	83.3	87.5	72.2	80.3	89.2	76.6	83.8	80.4	83.9	58.5	76.2	71.2	76.4	76.5	72
400	85.7	84.2	68.8	86.2	84.5	81.8	78.8	73.9	81	63.3	77.3	78.4	76.4	78.4	77
500	84.8	86.6	73.3	89.6	83.2	81.5	77.5	81.9	81.8	63.8	76.3	76.1	76.6	73.9	88.8
630	78.2	81.4	72.4	86.3	87.1	79.3	81.6	80.2	76.2	66.8	73.7	78.6	72.3	79.3	88.6
800	81.5	81.4	74.3	75.6	81.5	77	75.3	79.2	75.8	69.3	74	78.4	69.5	70.4	84.4
1000	78.6	80	75.3	82	83	81.4	74.3	79.2	74.4	71.5	72.6	80.6	68.2	71.9	79.4
1250	81.5	78.1	73.8	81.1	81	75.2	72.3	78.1	70.3	71.9	72.1	80.3	64.7	61.4	76.1
1600	80	80.2	75.8	77.4	80.8	72.2	70.3	86.2	67.8	73.9	71.9	79	61.3	60.8	75.2
2000	76.8	77.5	72.8	74	74.8	66.8	64.4	76.9	64.8	72.4	73	75	56.3	51.9	67
2500	76.7	72.6	75	71.8	72.6	63.7	61.1	75.6	61.6	72.1	65.4	75.1	54.1	47.4	62.3
3150	77.3	68.9	73.9	67.4	66.8	62.4	52.1	76.5	59	71.6	57	76.9	52.7	43.9	55.5
4000	73.8	64.4	73.9	62.6	59.9	60.4	43.3	74.9	58.3	70.5	50	74.6	49.3	40.9	49
5000	70	53.4	70.5	55.6	50.3	55.5	40.9	72.5	54.8	68.2	40.9	71.2	48.1	40.9	42.7
6300	64	40.9	70.2	51.2	40.9	54.8	40.9	70.4	51.6	65.4	40.9	69.6	44.9	40.9	40.9
8000	55.6	40.9	71.1	45.5	40.9	45.9	40.9	61.3	46.8	59.5	40.9	63.6	41.1	40.9	40.9
10000	43.9	40.9	61.9	40.9	40.9	40.9	40.9	48.7	43.9	52	40.9	55.9	40.9	40.9	40.9
12500	40.9	40.9	52.3	40.9	40.9	40.9	40.9	40.9	40.9	41.9	40.9	43.3	40.9	40.9	40.9
16000	40.9	40.9	43.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9
20000	40.9	40.9	54.2	40.9	40.9	40.9	40.9	45.3	40.9	44.4	40.9	47.6	40.9	40.9	40.9

1/3 OB (Hz)	TEST SIGNAL IDENTIFICATION NUMBER														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
25	40.9	40.9	40.9	53	45.1	42.7	40.9	40.9	40.9	40.9	40.9	45.7	40.9	40.9	50.9
31.5	40.9	46	48.1	56.9	52.7	40.9	40.9	40.9	45.3	48.7	40.9	50	44.4	41.9	50.9
40	49.6	57.2	59.3	69.2	67.7	51.1	53.2	42.7	59.2	57.8	54	66.2	59.2	56.9	62.4
50	56.5	63.6	66.4	71	75.3	60.1	62.9	48.8	68.6	60.9	60.7	74.2	69.2	68.5	72.4
63	70.3	66.6	68.3	90.1	73.9	62	65.3	52.6	64.6	62.2	66.6	74	72.6	71.6	72.3
80	89.5	64.5	69	82.3	76.3	63.3	65.2	56.6	62.4	69.8	67.3	76.3	75.1	72.2	72.2
100	67.5	61.8	69.1	75.3	82	65.5	79.8	84.1	66	79.7	67.6	85.6	76.9	75.8	76
125	65.6	73.3	67.3	83.8	89	66.2	76.5	88.1	76	86.6	67.6	92.5	77.4	76.9	73.3
160	83.2	77.2	74.3	86.4	90.8	66.2	75.7	66.4	79.1	84.6	69	96.4	78.8	78.9	71.6
200	71.2	81.6	80.3	77.9	83.4	65.6	85.3	69.9	80.6	79.8	69.5	90.1	76.3	76.3	67.2
250	76.6	81.8	82.9	78.6	87.3	64.6	80.5	73.8	79.1	82.6	75.1	87.2	77.2	78	76.9
315	73.9	75.3	82.1	73.5	88.2	61.3	80	79.6	76.7	85.8	82.3	85.6	78.7	80.3	82.6
400	64.9	82.1	80.3	77.3	85.8	68.9	81.2	74.6	83.5	83	81.8	85.8	79	80	85.4
500	69.5	79.8	84.8	77	85.4	81.4	77.6	76.8	82.7	82.9	73.8	83.5	78.8	80	83.9
630	65.4	81.4	78.2	73.9	86.4	88.9	76.9	75.8	83.3	86.9	78.9	79.9	77.3	79.4	77.4
800	61.1	79.7	77.5	69.5	82.6	83.2	79.8	68.3	80	81.8	78.5	75.7	79.5	79.9	81
1000	56.6	79.6	76	71.5	81.2	76.9	77.8	64.6	79.6	82.7	78	74	80.2	80.3	77.3
1250	52.5	78.4	72	69.9	77.9	80	76.2	61.3	78.6	80.9	74.4	71.5	77.4	78.1	80.9
1600	49.2	79.6	69.3	71.2	77.3	79.3	76.8	59.6	78.2	79.8	70.6	69.3	79.9	78.8	78.4
2000	44.4	76.2	66.9	70.6	71.9	75.9	73	51.3	75.8	75.6	63.6	63.8	77.4	76.3	73.8
2500	40.9	77.2	62	71.6	69.9	73.3	74.3	46.9	78.9	74.8	56.8	54.8	78.6	76.5	82
3150	40.9	82.6	59.2	70.1	62.4	68.9	74.2	42.7	79.1	71.2	46.3	45.7	77.6	74.5	87.2
4000	40.9	82.4	62.9	69.1	54.8	64.4	70.9	40.9	76.1	67.1	40.9	41.9	79	73.3	78.5
5000	40.9	78	59.9	65.3	44.9	59.4	67.3	40.9	72.9	58.9	40.9	40.9	82.5	69.4	67.6
6300	40.9	73.9	55.1	62.6	40.9	55.2	63.9	40.9	69.1	48.1	40.9	40.9	75.6	66.6	61.5
8000	40.9	69.2	54.3	56.4	40.9	48.5	57.2	40.9	62.2	40.9	40.9	40.9	72.6	61.6	55.9
10000	41.5	61.2	48.7	49.3	40.9	41.5	49.8	40.9	53.2	40.9	40.9	40.9	70.1	53.9	50.9
12500	40.9	48.5	41.9	41.9	40.9	40.9	40.9	40.9	41.9	40.9	40.9	40.9	47.4	40.9	50.9
16000	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	41.9	40.9	50.9
20000	40.9	52.6	41.9	42.7	40.9	40.9	42.7	40.9	46	40.9	40.9	40.9	59.3	46.3	50.9

Table 9 One-third octave band levels of test signals at time of maximum A-level for comparison with simulated takeoff test signal.

1/3 OB (Hz)	TEST SIGNAL IDENTIFICATION NUMBER														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
25	42.7	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	42.7
31.5	46.9	40.9	44.4	40.9	40.9	44.4	40.9	40.9	45.3	40.9	40.9	43.3	40.9	40.9	51.8
40	55.3	55.9	49.9	53.2	49.9	50.4	52	49.6	55.6	42.7	48.7	51.8	50.2	44.9	60.3
50	61.6	60.6	51.4	64.3	62.2	62.9	64.9	61.8	66.8	48.1	54.7	63.8	57.7	61.7	68.4
63	65.2	63.8	53.5	67.3	63	64.9	68	64.1	69.8	47.6	58.1	61.4	55.9	67.7	69.1
80	68.4	60.6	57.7	72.4	62.4	65	69.6	61.3	67.3	45.7	64.5	62.6	64.4	66.4	68.5
100	69.7	71.5	59.8	73.2	61.9	68.4	67.3	60.6	67.4	43.9	73.6	62.6	76.1	67.6	70.3
125	68	77.4	63.4	76.5	64.4	68	67.9	59.6	69.8	53.8	79.7	69.2	79.6	65.3	70.6
160	64.5	81.4	65.2	76.4	68	67.7	68.2	69.6	78.5	59.6	77.2	73.6	75.2	62.9	70.3
200	63	79.3	65.3	74.3	73.3	64.2	72.8	71.9	83.3	60.7	72.1	75.4	73.2	67.3	68.3
250	72.1	73.6	70.5	70.6	75.6	67.2	76.9	72.3	83.2	57.8	79.6	72.2	81.4	76.9	66.4
315	77.5	81.9	69.8	73.4	79.8	74	83	70.6	81.8	58.3	73.4	69.1	73.8	77.9	65.4
400	80.3	79.1	70.4	79.6	78.4	79.3	78.3	70.5	78.8	62.9	75.6	75.2	75.2	80.6	70.4
500	79	81	72.8	83	77.5	79.8	77.4	75.1	81.4	63.9	76.2	72	76.9	74.3	82
630	72.5	75.7	71.2	80.3	79.9	77.6	81.6	71.8	74.2	65.4	75.6	73.7	71.4	76.6	81.7
800	75.9	75.9	73	69.7	75.5	75.3	74.9	73.6	72.8	67.8	74.8	76.3	70.4	70.3	77.9
1000	73.4	74.5	75.6	75.1	76.6	80	74.2	73	73.3	70.3	73.8	77.4	67.3	70.4	72.9
1250	76	72.5	74.5	74	75.8	74.6	71.6	71.9	71	70.3	72.4	74.8	63.7	61.4	69.6
1600	74.2	74.6	75.5	70.6	73.7	70.1	69.8	78.8	68	74.2	72.3	75.3	60.5	58.3	68.6
2000	71.5	72.1	72.4	67.2	68.9	64.9	64	69.6	62.5	71.6	66.6	71.6	54.8	49.9	60.4
2500	71.3	67	74.3	65	66.5	61.6	60.6	68.5	66.8	71.8	65.2	71.4	52.8	46.9	55.8
3150	72	63.4	74	60.5	62	60.5	51.9	70.3	58.6	71.8	57.9	73.5	50.8	42.7	49.3
4000	68.4	58.7	73.7	55.7	54.2	58.3	42.7	68.2	56.5	70.9	52.4	70.9	49.5	40.9	43.3
5000	64.4	47.9	70.9	48.8	45.3	54	40.9	65.3	56.5	68	44.9	67.2	46.3	40.9	40.9
6300	58.6	40.9	70.9	44.9	40.9	52.8	40.9	63.3	51.3	64.6	40.9	65.5	44.9	40.9	40.9
8000	50.4	40.9	72.2	40.9	40.9	44.1	40.9	55.1	47.6	59.6	40.9	59.5	42.9	40.9	40.9
10000	41.5	40.9	62.6	40.9	40.9	40.9	40.9	45.9	43.9	52.6	40.9	52.1	40.9	40.9	40.9
12500	40.9	40.9	53.2	40.9	40.9	40.9	40.9	40.9	40.9	42.7	40.9	40.9	40.9	40.9	40.9
16000	40.9	40.9	44.4	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9
20000	40.9	40.9	55.3	40.9	40.9	40.9	40.9	40.9	40.9	44.9	40.9	44.4	40.9	40.9	40.9

1/3 OB (Hz)	TEST SIGNAL IDENTIFICATION NUMBER														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
25	40.9	40.9	40.9	53.5	40.9	40.9	42.7	40.9	40.9	40.9	40.9	44.9	40.9	40.9	40.9
31.5	40.9	40.9	46	55	51.6	40.9	40.9	40.9	40.9	43.9	40.9	47.4	40.9	40.9	44.4
40	47.9	53.2	58.1	70.2	64.1	43.9	49.3	44.4	54.2	51.7	52.5	59	53.8	58.9	49.3
50	56.2	56.2	63.5	70.5	76	52.9	60.2	50.9	63.6	54.3	57.8	68.8	65	65.8	58.4
63	71.2	57.3	65.9	90.2	71.4	55.3	62.2	53.9	59.4	55.9	63.7	68.6	67.4	67.4	63.1
80	89.2	54.8	67.2	84.2	68	56.8	62.8	56.4	56.8	62	66	72.4	66.8	69.9	66
100	66.4	57.5	67.5	76.1	77.9	58.8	75.7	83.2	60.7	72.6	66	80	69.9	73.4	67.6
125	66.6	67.2	64.9	83.2	81.8	59.5	73.3	87.4	71	78.3	67.2	87.4	69.8	72.3	65
160	83.3	73.1	72.3	87.3	85.5	59.3	71.3	66.3	73.7	77.4	68	89.6	71.4	74.9	63.7
200	73.1	74.5	78.7	78.8	81.8	58.8	81.9	70.1	75.4	73.3	68.5	83.5	72.6	72.2	60.9
250	78.2	74	80.3	79.1	76.8	57.8	78.2	74.3	73.8	76	73.9	82.3	70.6	74.5	70.9
315	75	71	80.2	73.8	84.2	54.7	77	79.9	71.4	78	81.2	80.8	71.4	75.8	76
400	65.4	75.4	77.8	76.4	77.4	62.2	78	75.2	78.4	76.3	80.8	81.5	73.1	76.2	78.2
500	69.8	74.4	82.1	76	81.1	74.5	75.1	77.3	77.5	75.8	72.8	78.6	73.3	76.4	77.2
630	67	74.5	75.7	74	76.9	82.2	74	76.4	78.6	80.8	76.9	74.9	72.7	75.6	71.3
800	61	72.9	75.3	70	75	76.5	77.3	68.9	74.8	74.8	76.9	69.3	72.9	75.8	74
1000	56.9	73.1	73.6	70.3	74	70.2	74.9	65	74.4	75.9	76.8	69.2	74.9	77.5	71.5
1250	52.8	71.8	69.5	69.7	71.5	73.3	72.8	61.6	73.3	74.3	73.3	65.5	71.4	73.6	74.3
1600	48.7	72.2	66.7	70.6	68.8	72.4	73.6	60.1	72.8	73.1	69	63.1	74.3	75.1	71.2
2000	43.9	68.9	64.3	69	62.9	69.3	69.9	51.8	70.6	68.9	62.2	58.6	71.9	72.1	66.8
2500	42.7	70.2	59.3	70.3	60.1	66.6	71.3	46.9	73.6	67.9	55.6	50.4	73	72.9	74.3
3150	40.9	73.3	56.6	69.8	52.1	62.2	70.3	42.7	73.8	63.8	45.3	41.9	72.2	71.4	80.6
4000	40.9	77	60.2	68.6	45.3	57.8	67.3	40.9	70.8	59.9	40.9	40.9	72.6	69.8	70.6
5000	40.9	71.8	57.3	65	40.9	53	63.8	40.9	67.5	51.8	40.9	40.9	77.8	66.6	59.4
6300	40.9	67.9	52.7	61.9	40.9	48.8	60.7	40.9	63.8	42.7	40.9	40.9	70.6	63	54.8
8000	40.9	63.9	52	56.1	40.9	42.9	54	40.9	57.1	40.9	40.9	40.9	67.4	58.4	48.1
10000	40.9	55.9	46.6	48.9	40.9	40.9	46.9	40.9	48.2	40.9	40.9	40.9	64.7	51.2	40.9
12500	40.9	43.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	42.7	40.9	40.9
16000	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9
20000	40.9	47.6	40.9	42.7	40.9	40.9	40.9	40.9	41.9	40.9	40.9	40.9	54	43.9	40.9

Table 10 Presentation levels of fixed test signals in terms of weighted metrics for comparison with Boeing 727 takeoff test signal.

ID #	Abbr.	Duration	TAVOA	MXMOA	OASEL	TAVA	MXMA	ASEL	TAVB	MXMB	BSEL	TAVC	MXMC	CSEL	TAVD	MXMD	DSEL	TAVE	MXME	ESEL
1	101L	11	87.1	92.5	97.7	85	90.4	95.6	86.4	91.9	97	90.2	95.7	100.8	90.2	95.7	100.8	88	93.7	98.6
2	101T	12.5	90.6	94.9	101.8	86	90.5	97.1	89.3	93.7	100.5	90.6	94.9	101.7	90.2	94.9	101.3	89.2	93.7	100.3
3	707L	10.5	80.6	85.4	91	80.2	85.1	90.6	80	84.9	90.4	80.2	85.1	90.6	87.6	92.1	98	84.7	89.3	95.1
4	727L	9	89.6	94.7	99.3	86.1	91.4	95.8	88.5	93.9	98.3	89.5	94.6	99.3	89.9	94.7	99.7	88.9	94.1	98.7
5	727T	11.5	91.1	95.2	101.9	87.2	91.6	98	90	94.4	100.8	91.1	95.2	101.8	90.8	95.2	101.6	90	94.3	100.8
6	737L	10	83.2	88.6	93.4	81	86.4	91.2	82.6	88.2	92.8	83.1	88.6	93.3	83.8	89	94	83	88.5	93.2
7	737T	13.5	84.5	88.6	95.9	80.1	84.8	91.6	83.5	87.9	94.9	84.4	88.6	95.9	83.7	88.2	95.2	83.3	87.8	94.7
8	747L	12	88.1	91.9	99.1	86.9	90.7	97.8	87.5	91.2	98.5	88	91.8	98.9	92.6	96	103.5	90.1	93.5	101.1
9	747T	12	88.7	93	99.7	82	86.3	92.9	87.2	91.7	98.2	88.7	93	99.6	87.3	91.6	98.2	86.4	90.7	97.3
10	757L	10.5	76.2	81.6	86.6	76.7	82.2	87.1	75.9	81.4	86.3	76	81.3	86.4	83.8	89.3	94.2	80.7	86.3	91.1
11	757T	12.5	84.1	88.6	95.3	78.8	83	90	82.5	86.8	93.6	84.1	88.5	95.2	83.2	88	94.3	82.1	86.4	93.2
12	767L	12	85.9	89.6	96.9	84.5	88.5	95.5	85.1	89.1	96.1	85.7	89.5	96.7	90.8	94.3	101.8	88.2	91.8	99.2
13	767T	12.5	83.1	87.4	94.3	76.3	80.1	87.4	81.3	85.4	92.4	83.1	87.3	94.2	81.2	85.2	92.3	80.5	84.5	91.6
14	777T	12.5	81.6	85.8	92.8	75.8	81.3	86.9	80.3	84.5	91.5	81.6	85.7	92.7	80.2	84.4	91.4	79.7	84.3	90.8
15	B1BF	7	89.3	93.6	98	85.1	91.1	93.8	87.9	93	96.6	89.2	93.5	97.9	87.9	93.1	96.5	87.7	93.2	96.3
16	DS8T	16	85.1	90.9	97.3	70.7	75.7	82.9	79.4	85.4	91.6	84.7	90.5	96.8	78.5	84.4	90.7	77.4	83.3	89.6
17	D10L	11	87.9	92.4	98.5	86.6	91.1	97.2	87.2	91.6	97.8	87.7	92.1	98.3	93.4	98.8	104	90.8	96.1	101.4
18	D10T	12	88	91.1	98.9	82.3	86.3	93.2	86.6	89.8	97.5	87.9	91.1	98.8	86.8	90.3	97.8	86.1	89.6	97.1
19	DC7L	11	87.3	94	97.8	77.9	83.4	88.5	83.2	89.7	93.8	86.9	93.6	97.5	84.3	90.7	94.9	82.6	88.6	93.1
20	DC8T	14.5	93.8	99	105.5	86.8	91.3	98.6	91.7	96.8	103.4	93.6	98.9	105.4	91.6	96.5	103.3	90.7	95.6	102.5
21	F11F	4.5	85.7	91.6	92.6	84.3	90.5	91.2	85.2	91.5	92.2	85.6	91.6	92.6	87.3	93.3	94.3	86	92.2	92.9
22	J31L	15.5	85.2	91.2	97.3	81.6	87.3	93.7	84	90	96	85.1	91.1	97.2	86.9	93	98.9	84.9	91	97
23	J31T	14.5	89.1	95.4	100.9	74.8	80.5	86.5	84.5	90.3	96.2	88.9	95.1	100.6	83.3	88.9	95	82.1	87.6	93.8
24	M11L	11.5	87.7	92	98.4	85.9	90.1	96.6	87	91.4	97.8	87.5	91.9	98.3	91.7	96.3	102.5	89.3	94	100.1
25	M11T	11.5	90.1	94.8	100.9	85.5	91.2	96.3	88.6	93.7	99.4	90.1	94.8	100.8	89.8	95	100.5	88.5	93.8	99.3
26	M82T	14.5	85.8	88.8	97.5	81.8	85.1	93.6	84.9	88.2	96.7	85.7	88.8	97.5	85.2	88.5	97	84.9	88.2	96.6
27	SIMT	8	95.2	99.7	104.4	84.9	89.4	94.2	92.5	97	101.8	95.1	99.6	104.3	91.8	96.3	101.1	90.6	95.2	99.9
28	ST5L	11.5	86.3	91.7	97.1	84.9	90.4	95.7	85.4	90.7	96.2	86.1	91.3	96.9	90.9	97.7	101.7	88.5	95.3	99.3
29	ST6T	13.5	87.7	90.8	99.1	85.6	88.6	97	86.8	89.9	98.3	87.5	90.7	99	90.7	94.1	102.2	88.6	91.8	100
30	101S	10	78	83.4	88.2	76.9	82.4	87.1	77.4	82.8	87.6	77.9	83.2	88.1	84.8	90.7	95	81.8	87.6	92

Table 11 Presentation levels of fixed test signals in terms of calculated metrics for comparison with Boeing 727 takeoff test signal.

ID #	Abbr.	Duration	TAVPNL	MXMPNL	EPNL(NT)	TAVPNLT	MXMPNLT	EPNL	TAVLLZ	MXMLLZ	LLZSEL	TAVPLS	MXMPLS	PLSSEL
1	101L	11	96.5	101.9	107.1	97.7	103	108.3	100.3	105.5	110.9	86.5	92.1	97.1
2	101T	12.5	96.7	101.3	107.9	98.3	102.6	109.4	100.5	104.7	111.6	87.6	92.2	98.7
3	707L	10.5	93.5	97.9	103.9	95.1	98.8	105.5	96.8	101.6	107.3	83.4	87.9	93.8
4	727L	9	96.8	102	106.6	98.1	103.2	107.9	100.5	104.9	110.2	87.6	92.9	97.4
5	727T	11.5	97.2	101.3	108	98.5	103	109.3	101.1	105	111.9	88.2	92.4	98.9
6	737L	10	90.4	95.4	100.6	91.9	97.2	102.1	95.6	100.3	105.8	81.4	86.4	91.6
7	737T	13.5	90.1	94.5	101.6	91.5	96.2	103	94.6	98.4	106	81.3	85.4	92.8
8	747L	12	99.2	103.1	110.2	101.2	106	112.1	102.4	105.9	113.3	88.9	92.6	99.9
9	747T	12	93.7	98.4	104.6	95.4	100.4	106.4	97	101.2	108	84.5	88.8	95.4
10	757L	10.5	88.8	94.3	99.2	89.7	94.6	100.1	92.3	97.5	102.7	78.8	84.1	89.1
11	757T	12.5	89.6	94.5	100.7	90.8	96	102	94.6	98.5	105.7	80.7	84.9	91.8
12	767L	12	97.4	101	108.4	98.9	103.7	109.8	100.8	104.4	111.8	87.3	90.9	98.2
13	767T	12.5	87.7	91.4	98.8	88.7	92.6	99.8	92.2	95.6	103.3	79	82.6	90.1
14	777T	12.5	86.5	90.8	97.6	88.2	92.6	99.3	91.3	95.2	102.4	77.8	81.6	88.9
15	B1BF	7	94.3	99.4	103	95.6	101	104.3	97.7	102.2	106.4	85.4	90.4	94.1
16	DS8T	16	84.5	90.1	96.7	86.4	92.5	98.5	88.8	92.7	100.9	75.3	80.3	87.5
17	D10L	11	99.9	105.3	110.5	101.2	106.7	111.8	102.6	107	113.2	89.8	95.5	100.4
18	D10T	12	93.7	97.4	104.6	95.3	99.2	106.3	97.6	101.2	108.6	84.6	88.4	95.5
19	DC7L	11	91.6	97.9	102.2	92.6	99	103.2	96.4	102.2	107	82.4	88.4	93
20	DC8T	14.5	97.9	102.7	109.7	98.9	103.9	110.6	101.1	105.2	112.9	88.8	93.4	100.6
21	F11F	4.5	93.4	99.4	100.3	95.2	101.6	102.1	97.6	102.3	104.5	84.2	90.3	91.1
22	J31L	15.5	93.6	99.8	105.7	95.4	101.3	107.4	98.4	103.7	110.4	84.1	90	96.2
23	J31T	14.5	89.2	94.9	100.9	92.3	98.2	104.1	91.6	96	103.4	79.5	84.7	91.2
24	M11L	11.5	98.2	103	109	99.3	103.6	110.1	101.8	105.9	112.6	88.1	93	98.9
25	M11T	11.5	96.3	101.8	107	97.3	103.3	108.1	100.5	105.3	111.3	87.1	92.7	97.9
26	M82T	14.5	91.5	95	103.3	92.6	96.1	104.3	95.6	98.3	107.4	82.6	85.8	94.4
27	SIMT	8	97.3	101.9	106.6	98	102.7	107.3	98.7	102.6	107.9	88.1	92.9	97.4
28	ST5L	11.5	97.8	105	108.6	98.7	106.7	109.5	101.1	106.8	111.9	87.9	95.1	98.6
29	ST6T	13.5	97.5	101.1	108.9	98.2	101.5	109.6	101.5	104.6	112.9	87.4	90.8	98.9
30	101S	10	90.8	96.4	101	93.2	98.9	103.4	93	98	103.2	80.3	86	90.5

Table 12 Presentation levels of fixed test signals in terms of weighted metrics for comparison with simulated takeoff test signal.

ID #	Abbr.	Duration	TAVOA	MXMOA	OASEL	TAVA	MXMA	ASEL	TAVB	MXMB	BSEL	TAVC	MXMC	CSEL	TAVD	MXMD	DSEL	TAVE	MXME	ESEL
1	101L	11	81.7	87	92.3	79.6	84.8	90.2	81	86.4	91.5	81.6	86.9	92.2	84.7	90.4	95.3	82.6	88.2	93.2
2	101T	12.5	85.1	89.3	96.2	80.4	84.9	91.5	83.8	88.2	94.9	85	89.3	96.1	84.7	89.4	95.8	83.6	88.2	94.7
3	707L	11	80.4	85.2	91	80	85	90.6	79.9	84.7	90.5	80	84.8	90.6	87.4	92	98	84.4	89.2	95
4	727L	8.5	83.3	88.3	92.8	79.7	84.8	89.2	82.2	87.4	91.7	83.2	88.3	92.7	83.6	88.1	93.1	82.6	87.6	92.1
5	727T	11.5	84.3	88.3	95.1	80.5	84.9	91.2	83.2	87.5	94	84.3	88.3	95	84.1	88.4	94.9	83.2	87.5	94
6	737L	9.5	81.3	86.8	91.3	79.2	84.8	89.2	80.7	86.4	90.7	81.3	86.8	91.3	82	87.2	91.9	81.2	86.7	91.2
7	737T	13.5	84.1	88.2	95.6	79.8	84.5	91.2	83.1	87.5	94.6	84.1	88.1	95.5	83.4	87.8	94.8	83	87.4	94.4
8	747L	12.5	81.1	85.1	92.2	79.8	83.8	91	80.5	84.4	91.7	81	85	92.1	85.6	89.5	96.7	83.2	86.7	94.3
9	747T	12	86.7	91	97.7	79.9	84.2	90.9	85.2	89.7	96.2	86.6	91	97.6	85.2	89.6	96.2	84.3	88.7	95.3
10	757L	10.5	76.3	81.2	86.7	76.8	81.8	87.2	76	80.9	86.4	76.1	80.9	86.5	84	89.4	94.4	80.9	86.2	91.3
11	757T	12.5	84.1	88.4	95.2	78.7	82.6	89.9	82.4	86.4	93.6	84	88.3	95.1	83.1	87	94.2	82	85.6	93.1
12	767L	12	82.1	86.1	93.1	80.8	84.8	91.7	81.4	85.4	92.3	81.9	85.9	92.9	87.1	90.6	98.1	84.5	88.2	95.5
13	767T	13	82.9	86.7	94.2	76.1	79.7	87.4	81.1	84.9	92.4	82.9	86.6	94.2	81	84.7	92.3	80.3	83.9	91.6
14	777T	12.5	81.9	85.7	93	76.1	80.9	87.2	80.6	84.7	91.8	81.9	85.6	93	80.5	84.6	91.7	80	84.6	91.1
15	B1BF	7	82.6	86.9	91.2	78.4	84.3	87.1	81.2	86.3	89.9	82.5	86.8	91.1	81.2	86.4	89.8	81	86.4	89.6
16	DS8T	15.5	85.2	90.8	97.3	71.1	76.4	83.1	79.7	85.7	91.7	84.8	90.4	96.8	78.8	84.7	90.9	77.7	83.6	89.7
17	D10L	11	81	85.7	91.6	79.7	84.3	90.3	80.4	84.9	91	80.8	85.4	91.4	86.5	91.9	97.1	84	89.3	94.6
18	D10T	12	85.7	88.8	96.6	79.9	83.8	90.9	84.3	87.5	95.2	85.6	88.8	96.5	84.5	87.9	95.5	83.8	87.2	94.7
19	DC7L	11	87.4	94.2	98	77.8	83.1	88.4	83.3	89.5	93.9	87.1	93.8	97.7	84.3	90.5	94.9	82.6	88.5	93.2
20	DC8T	14	87.1	92	98.7	80.2	84.6	91.8	85	89.7	96.6	86.9	91.9	98.6	84.9	89.4	96.5	84.1	88.7	95.7
21	F11F	4.5	78.9	84.9	85.8	77.5	83.7	84.4	78.5	84.8	85.4	78.8	84.9	85.8	80.6	86.6	87.5	79.2	85.5	86.2
22	J31L	15.5	82.3	88.2	94.4	78.8	84.3	90.8	81.1	86.9	93.1	82.2	88.2	94.3	84	89.8	96.1	82.1	87.8	94.1
23	J31T	14.5	89.2	95.5	100.9	74.8	80.8	86.6	84.5	90.5	96.2	88.9	95.2	100.7	83.3	89.2	95.1	82.1	87.8	93.8
24	M11L	11.5	82.4	86.9	93.2	80.7	84.9	91.4	81.8	86.3	92.5	82.3	86.8	93.1	86.5	91.1	97.3	84.1	88.7	94.9
25	M11T	11.5	83.3	87.8	94.1	78.9	84.5	89.6	81.9	86.8	92.6	83.3	87.7	94	83.1	88.2	93.8	81.8	87	92.6
26	M82T	14.5	84.7	87.5	96.4	80.7	83.8	92.5	83.9	86.9	95.6	84.6	87.5	96.4	84.1	87.2	95.9	83.8	86.9	95.5
27	SIMT	7.5	90.5	94.4	99.5	80.1	84	89.2	87.8	91.6	96.8	90.4	94.3	99.4	87.1	90.9	96.2	86	89.7	95
28	ST5L	11	81	85.9	91.6	79.6	84.9	90.2	80.1	85	90.7	80.8	85.5	91.4	85.6	92.3	96.2	83.3	90	93.9
29	ST6T	13	84.4	87.3	95.7	82.4	85	93.7	83.6	86.4	94.9	84.3	87.2	95.6	87.5	90.5	98.8	85.4	88.2	96.6
30	101S	9.5	81.4	86.5	91.4	80.3	85.5	90.3	80.7	86	90.7	81.2	86.3	91.2	88.1	93.8	98.1	85.1	90.7	95.1

Table 13 Presentation levels of fixed test signals in terms of calculated metrics for comparison with simulated takeoff test signal.

ID #	Abbr.	Duration	TAVPNL	MXMPNL	EPNL(NT)	TAVPNLT	MXMPNLT	EPNL	TAVLLZ	MXMLLZ	LLZSEL	TAVPLS	MXMPLS	PLSSEL
1	101L	11	91	96.6	101.6	92.1	97.7	102.7	95.6	100.8	106.2	81.3	86.6	91.9
2	101T	12.5	91.2	95.6	102.4	92.8	96.8	103.9	95.8	100	106.9	82.2	86.7	93.3
3	707L	11	93.4	97.9	104	95	99.1	105.6	96.7	101.5	107.3	83.2	87.9	93.8
4	727L	8.5	90.4	95.3	99.9	91.7	96.5	101.2	95.1	99.3	104.6	81.4	86.2	90.9
5	727T	11.5	90.5	94.7	101.2	91.8	96.3	102.6	95.4	99.2	106.2	81.6	85.5	92.3
6	737L	9.5	88.6	93.5	98.6	90.1	95.2	100	94	98.7	104	79.7	84.6	89.7
7	737T	13.5	89.8	94	101.3	91.2	95.8	102.7	94.3	98.1	105.8	81	85	92.4
8	747L	12.5	92.3	96.3	103.4	94.1	99	105.3	96.3	99.9	107.5	82.1	85.7	93.2
9	747T	12	91.7	96.3	102.6	93.4	98.5	104.4	95.2	99.6	106.2	82.4	86.8	93.4
10	757L	10.5	88.8	94.2	99.2	89.8	95.3	100.2	92.4	97.1	102.7	78.9	83.9	89.3
11	757T	12.5	89.3	93.4	100.5	90.7	94.6	101.8	94.5	98	105.7	80.6	84.2	91.8
12	767L	12	93.6	97.6	104.6	95.1	99.8	106.1	97.6	101.3	108.5	83.6	87.3	94.5
13	767T	13	87.5	91.3	98.8	88.6	92.6	99.8	92	95.2	103.3	78.8	82.3	90.1
14	777T	12.5	86.8	90.9	97.9	88.3	92.4	99.4	91.5	95.4	102.6	78	82	89.2
15	B1BF	7	87.6	92.6	96.3	88.9	94.3	97.6	92.3	96.6	100.9	79	83.7	87.6
16	DS8T	15.5	84.7	89.8	96.8	86.5	91.6	98.6	88.9	93	101	75.5	80.6	87.6
17	D10L	11	93.1	98.8	103.7	94.4	100.3	105	96.7	101.2	107.3	82.9	88.6	93.5
18	D10T	12	91.4	95	102.3	93	96.5	104	95.6	99.1	106.6	82.3	85.9	93.3
19	DC7L	11	91.7	97.8	102.2	92.7	98.9	103.3	96.4	102	107	82.5	88.4	93.1
20	DC8T	14	91.3	95.8	102.9	92.3	97.2	103.9	95.7	99.4	107.3	82.4	86.9	94
21	F11F	4.5	86.7	92.6	93.6	88.4	94.8	95.4	91.8	96.5	98.7	77.8	83.5	84.7
22	J31L	15.5	90.7	96.3	102.7	92.5	98.3	104.5	95.9	101	107.9	81.4	86.8	93.4
23	J31T	14.5	89.3	95	101.1	92.5	98.4	104.2	91.7	96.2	103.4	79.5	84.9	91.2
24	M11L	11.5	93	97.8	103.8	94.1	98.5	104.9	97.3	101.4	108.1	83	87.7	93.8
25	M11T	11.5	89.6	95	100.3	90.7	96.9	101.5	94.8	99.4	105.6	80.8	86	91.6
26	M82T	14.5	90.4	93.5	102.2	91.5	94.5	103.3	94.7	97.2	106.5	81.6	84.5	93.4
27	SIMT	7.5	92.7	96.7	101.7	93.4	97.5	102.5	94.9	98.2	103.8	83.5	87.4	92.5
28	ST5L	11	92.5	99.4	103.1	93.6	101.5	104.2	96.6	102	107.2	82.7	89.5	93.3
29	ST6T	13	94.2	97.4	105.5	95.1	98.2	106.3	98.7	101.5	110	84.3	87.3	95.6
30	101S	9.5	94.1	99.9	104.1	96.6	102.7	106.6	95.9	100.7	105.9	83.6	89.2	93.6

APPENDIX C Tabulations of Averaged Results

Table 14 Difference between variable (727T) and fixed test signal at judged equal annoyance using weighted metrics.

ID #	Abbr.	TAVOA	MXMOA	OASEL	TAVA	MXMA	ASEL	TAVB	MXMB	BSEL	TAVC	MXMC	CSEL	TAVD	MXMD	DSEL	TAVE	MXME	ESEL
1	101L	9.0	7.8	9.3	7.2	6.3	7.5	8.6	7.5	8.8	5.8	4.5	6.1	5.6	4.6	5.9	7.0	5.7	7.2
2	101T	2.8	2.4	2.6	3.4	3.7	3.3	2.9	2.8	2.7	2.7	2.3	2.6	2.9	2.7	2.8	3.0	3.0	2.9
3	707L	16.3	15.7	16.7	12.8	12.3	13.2	15.8	15.3	16.1	16.6	15.9	17.0	9.0	8.9	9.4	11.1	10.8	11.4
4	727L	3.0	1.8	4.3	2.5	2.0	3.8	2.9	1.8	4.1	3.0	1.8	4.2	2.4	2.1	3.6	2.5	1.8	3.7
5	727T	0.6	0.4	0.7	0.5	0.9	0.7	0.5	0.5	0.7	0.5	0.3	0.8	0.6	0.7	0.7	0.5	0.8	0.7
6	737L	1.6	0.3	2.1	-0.1	-1.2	0.4	1.0	-0.1	1.6	1.6	0.3	2.2	0.7	-0.2	1.3	0.6	-0.5	1.2
7	737T	0.4	0.4	-0.3	0.9	0.5	0.1	0.2	0.3	-0.4	0.4	0.4	-0.3	0.9	0.7	0.2	0.4	0.3	-0.2
8	747L	10.5	10.9	10.3	7.7	8.3	7.6	9.9	10.7	9.7	10.5	11.0	10.4	5.7	6.6	5.5	7.3	8.3	7.1
9	747T	-1.3	-1.5	-1.5	1.5	1.5	1.4	-1.0	-1.0	-1.2	-1.4	-1.5	-1.5	-0.2	-0.2	-0.3	-0.2	-0.1	-0.3
10	757L	11.3	10.0	11.7	6.9	5.7	7.3	10.4	9.4	10.8	11.4	10.3	11.8	3.4	2.2	3.8	5.6	4.4	6.0
11	757T	2.4	2.0	1.9	3.8	3.9	3.3	2.8	3.0	2.5	2.3	2.1	2.0	3.0	2.5	2.7	3.2	3.3	2.9
12	767L	11.6	12.1	11.4	9.1	9.5	8.9	11.3	11.7	11.0	11.7	12.1	11.5	6.4	7.3	6.2	8.2	8.9	7.9
13	767T	1.4	1.2	0.9	4.3	4.8	3.9	2.0	2.4	1.7	1.3	1.3	1.0	3.0	3.3	2.7	2.8	3.2	2.5
14	777T	1.3	1.3	0.9	3.2	2.1	2.9	1.5	1.8	1.1	1.2	1.4	0.9	2.4	2.6	2.0	2.1	1.9	1.8
15	B1BF	1.0	0.7	3.2	1.3	-0.0	3.5	1.2	0.6	3.5	1.0	0.7	3.3	2.1	1.4	4.4	1.4	0.5	3.8
16	DS8T	-5.8	-7.6	-7.0	4.6	4.4	3.4	-1.3	-2.8	-2.5	-5.5	-7.2	-6.6	0.5	-0.9	-0.8	0.7	-0.7	-0.5
17	D10L	11.8	11.5	12.0	9.1	8.9	9.3	11.3	11.4	11.5	11.9	11.8	12.1	6.0	4.9	6.1	7.7	6.8	7.9
18	D10T	3.0	3.8	3.0	4.7	5.5	4.8	3.2	4.4	3.3	3.0	3.7	3.1	3.9	4.9	3.8	3.7	4.8	3.7
19	DC7L	0.7	-1.9	1.0	6.2	5.0	6.4	3.6	1.6	3.8	1.0	-1.5	1.2	3.4	1.3	3.6	4.2	2.6	4.5
20	DC8T	-1.4	-2.7	-2.1	1.6	1.9	0.8	-0.5	-1.3	-1.2	-1.3	-2.7	-2.1	0.5	0.1	-0.2	0.5	0.1	-0.3
21	F11F	8.1	6.1	12.2	5.5	4.1	9.6	7.4	5.4	11.4	8.1	6.0	12.1	6.2	4.7	10.2	6.6	4.9	10.7
22	J31L	6.6	4.5	5.4	6.2	5.3	5.1	6.6	5.0	5.6	6.6	4.5	5.5	4.6	3.0	3.5	5.7	4.2	4.6
23	J31T	-5.9	-8.0	-6.9	4.5	3.2	3.6	-2.4	-3.7	-3.3	-5.8	-7.7	-6.7	-0.4	-1.6	-1.3	-0.0	-1.1	-0.9
24	M11L	9.6	9.5	9.7	7.5	7.7	7.6	9.2	9.2	9.1	9.7	9.5	9.7	5.3	5.1	5.3	6.9	6.5	6.8
25	M11T	2.4	1.6	2.6	3.0	2.1	3.2	2.7	1.9	2.9	2.3	1.5	2.6	2.4	1.7	2.7	2.8	2.0	3.0
26	M82T	-0.3	0.8	-1.3	-0.2	0.8	-1.3	-0.6	0.6	-1.6	-0.3	0.8	-1.3	0.0	1.0	-1.0	-0.6	0.5	-1.5
27	SIMT	-8.2	-8.6	-6.6	-1.8	-2.0	-0.3	-6.7	-6.7	-5.2	-8.2	-8.5	-6.6	-5.1	-5.3	-3.6	-4.8	-5.0	-3.3
28	ST5L	14.3	13.1	14.3	11.7	10.5	11.7	14.0	13.2	14.0	14.4	13.5	14.4	9.4	6.9	9.3	10.9	8.5	10.9
29	ST6T	14.0	15.1	13.4	12.1	13.5	11.5	13.7	15.1	13.0	14.1	15.2	13.4	10.7	11.6	9.9	11.9	13.1	11.3
30	101S	10.6	9.3	11.3	7.8	6.7	8.5	10.0	9.1	10.7	10.6	9.5	11.3	3.5	2.0	4.2	5.6	4.3	6.3

Table 15 Difference between variable (727T) and fixed test signal at judged equal annoyance using calculated metrics.

ID #	Abbr.	TAVPNL	MXMPNL	EPNL(NT)	TAVPNLT	MXMPNLT	EPNL	TAVLLZ	MXMLLZ	LLZSEL	TAVPLS	MXMPLS	PLSSEL
1	101L	5.9	4.9	6.2	6.1	5.4	6.3	5.3	3.9	5.5	7.0	5.7	7.2
2	101T	3.0	2.6	2.8	2.7	2.8	2.6	2.7	2.3	2.6	3.1	2.6	2.9
3	707L	9.7	9.7	10.1	9.5	10.4	9.8	9.4	8.4	9.6	10.9	10.8	11.3
4	727L	2.0	1.1	3.2	2.0	1.3	3.2	1.9	1.4	3.2	2.2	1.0	3.3
5	727T	0.6	0.8	0.8	0.6	0.6	0.8	0.5	0.5	0.7	0.6	0.6	0.8
6	737L	0.5	-0.1	1.1	0.3	-0.2	0.9	0.2	-0.6	0.8	0.5	-0.4	1.1
7	737T	0.9	0.9	0.2	0.8	0.9	0.1	1.2	1.3	0.6	0.7	0.7	0.0
8	747L	5.6	6.2	5.4	5.0	4.9	4.8	5.2	5.5	5.0	7.2	7.9	7.0
9	747T	-0.3	-0.3	-0.4	-0.7	-0.7	-0.9	0.9	0.6	0.7	-0.1	-0.2	-0.2
10	757L	4.7	3.9	5.1	5.1	5.2	5.5	5.7	4.4	6.1	5.7	4.6	6.2
11	757T	3.0	2.6	2.7	3.1	2.7	2.7	2.6	2.6	2.3	2.9	2.8	2.6
12	767L	6.4	7.2	6.2	6.3	6.1	6.1	5.9	6.1	5.6	7.6	8.4	7.5
13	767T	2.9	3.6	2.6	3.2	4.1	2.9	3.3	3.8	3.0	2.7	3.2	2.4
14	777T	2.6	2.7	2.3	2.2	2.4	1.9	2.9	2.9	2.6	2.4	2.7	2.1
15	B1BF	2.0	1.4	4.3	2.0	1.2	4.3	2.6	2.1	4.9	1.9	1.1	4.1
16	DS8T	0.9	-0.4	-0.3	0.3	-1.4	-0.8	2.5	2.3	1.3	1.8	0.6	0.5
17	D10L	6.0	5.1	6.2	6.0	5.3	6.2	5.9	5.3	6.0	7.4	6.2	7.6
18	D10T	3.3	4.0	3.4	3.0	3.6	3.0	3.3	3.7	3.3	3.4	3.8	3.4
19	DC7L	2.4	0.8	2.6	2.7	1.3	2.9	2.0	0.1	2.2	2.6	0.8	2.8
20	DC8T	0.7	0.2	-0.1	1.0	0.4	0.3	1.1	0.9	0.3	0.8	0.3	-0.1
21	F11F	6.7	4.9	10.8	6.2	4.2	10.3	6.0	5.1	10.1	6.9	4.9	10.9
22	J31L	4.3	2.4	3.2	3.8	2.4	2.8	3.3	1.9	2.3	4.8	3.1	3.6
23	J31T	0.2	-1.1	-0.7	-1.6	-2.9	-2.6	2.9	2.3	1.9	1.0	-0.1	0.1
24	M11L	5.4	5.0	5.4	5.7	6.0	5.6	4.7	4.4	4.7	6.6	6.1	6.6
25	M11T	2.4	1.2	2.7	2.7	1.1	2.9	1.8	0.9	2.0	2.6	1.1	2.7
26	M82T	0.1	1.0	-0.9	0.3	1.6	-0.6	0.7	1.9	-0.3	-0.0	0.9	-1.0
27	SIMT	-4.3	-4.3	-2.8	-3.7	-3.4	-2.2	-1.1	-1.1	0.5	-4.1	-4.7	-2.6
28	ST5L	9.0	6.3	9.0	9.4	6.2	9.4	8.1	6.2	8.1	10.2	7.5	10.3
29	ST6T	10.4	11.3	9.8	11.0	12.5	10.4	8.6	9.3	8.0	12.0	13.1	11.3
30	101S	3.8	2.9	4.5	2.7	1.9	3.4	5.9	4.9	6.6	5.3	3.8	6.0

Table 16 Difference between variable (SIMT) and fixed test signal at judged equal annoyance using weighted metrics.

ID #	Abbr.	TAVOA	MXMOA	OASEL	TAVA	MXMA	ASEL	TAVB	MXMB	BSEL	TAVC	MXMC	CSEL	TAVD	MXMD	DSEL	TAVE	MXME	ESEL
1	101L	14.3	13.2	13.0	6.1	5.3	4.8	12.3	11.2	11.1	14.3	13.2	12.9	7.9	6.5	6.6	8.9	7.6	7.6
2	101T	10.0	10.0	8.2	4.4	4.3	2.6	8.6	8.5	6.8	10.0	9.9	8.1	7.0	6.6	5.2	7.0	6.7	5.2
3	707L	19.8	19.5	18.5	10.0	9.4	8.6	17.6	17.3	16.3	20.1	19.8	18.8	9.5	9.4	8.1	11.3	11.0	10.0
4	727L	10.7	10.1	10.5	4.0	3.3	3.8	9.1	8.4	8.9	10.7	10.0	10.5	7.1	7.0	6.8	6.9	6.3	6.7
5	727T	9.6	9.9	8.1	3.1	3.1	1.7	8.0	8.1	6.5	9.5	9.8	8.0	6.4	6.5	4.9	6.2	6.2	4.7
6	737L	8.4	6.9	7.7	0.2	-1.1	-0.6	6.3	4.6	5.6	8.3	6.8	7.6	4.3	3.2	3.7	3.9	2.6	3.2
7	737T	9.7	9.9	7.5	3.7	3.4	1.6	8.0	8.0	5.8	9.6	9.9	7.5	7.0	7.0	4.9	6.3	6.3	4.2
8	747L	15.8	16.1	14.0	6.8	7.3	4.9	13.7	14.2	11.8	15.8	16.1	13.9	7.9	8.4	6.1	9.2	10.1	7.4
9	747T	6.8	6.9	5.1	3.3	3.4	1.6	5.6	5.6	3.9	6.8	6.8	5.1	5.0	5.0	3.2	4.7	4.7	3.0
10	757L	17.4	16.8	16.3	6.6	6.0	5.5	15.0	14.5	13.9	17.5	17.0	16.4	6.4	5.3	5.2	8.3	7.4	7.2
11	757T	11.2	11.1	9.4	6.3	6.8	4.4	10.2	10.5	8.3	11.2	11.1	9.3	8.8	9.2	7.0	8.8	9.5	7.0
12	767L	17.2	17.7	15.5	8.3	8.8	6.7	15.3	15.8	13.7	17.3	17.8	15.6	8.9	9.9	7.2	10.3	11.1	8.6
13	767T	10.5	11.1	8.5	7.0	7.8	5.0	9.6	10.3	7.6	10.4	11.1	8.4	9.1	9.8	7.0	8.6	9.4	6.6
14	777T	10.3	10.7	8.5	5.8	5.3	3.9	8.9	9.0	7.0	10.2	10.7	8.4	8.3	8.5	6.4	7.6	7.4	5.8
15	B1BF	8.2	7.9	8.9	2.1	0.5	2.6	6.9	5.8	7.5	8.2	7.9	8.9	6.2	5.1	6.9	5.2	4.1	5.9
16	DS8T	2.5	1.2	-0.3	6.3	5.4	3.6	5.3	3.6	2.6	2.8	1.5	0.1	5.5	3.9	2.7	5.5	4.0	2.8
17	D10L	17.5	17.2	16.2	8.6	8.5	7.3	15.5	15.4	14.2	17.6	17.4	16.3	8.7	7.7	7.4	10.0	9.2	8.7
18	D10T	10.4	11.5	8.8	5.9	6.4	4.2	9.1	10.2	7.5	10.4	11.4	8.7	8.2	9.1	6.5	7.8	8.7	6.2
19	DC7L	7.4	4.9	6.1	6.7	5.8	5.4	8.8	7.0	7.5	7.6	5.2	6.2	7.1	5.3	5.8	7.7	6.1	6.4
20	DC8T	7.7	7.1	5.4	4.3	4.3	2.0	7.1	6.8	4.8	7.8	7.1	5.3	6.5	6.4	4.2	6.2	5.9	3.9
21	F11F	13.3	11.5	15.7	4.4	2.5	6.7	11.0	8.9	13.4	13.3	11.4	15.6	8.2	6.5	10.6	8.4	6.5	10.7
22	J31L	15.5	14.0	12.7	8.8	7.7	6.1	14.1	12.7	11.4	15.5	13.9	12.7	10.5	9.1	7.7	11.2	9.9	8.5
23	J31T	1.6	-0.7	-0.8	5.7	4.0	3.1	3.6	1.6	1.2	1.8	-0.5	-0.7	4.1	2.3	1.6	4.1	2.7	1.7
24	M11L	14.9	14.7	13.4	6.3	6.6	4.9	12.8	12.7	11.4	14.9	14.7	13.3	7.4	7.2	5.9	8.7	8.5	7.2
25	M11T	11.0	10.9	9.5	5.1	3.9	3.7	9.7	9.3	8.3	10.9	10.9	9.5	7.9	7.2	6.4	8.0	7.2	6.5
26	M82T	9.0	10.5	6.6	2.7	4.0	0.2	7.1	8.5	4.7	9.0	10.4	6.5	6.3	7.5	3.7	5.4	6.7	3.0
27	SIMT	-0.9	-0.8	-0.6	-0.8	-0.4	-0.7	-0.9	-0.7	-0.6	-0.9	-0.8	-0.6	-0.9	-0.6	-0.7	-1.0	-0.4	-0.7
28	ST5L	18.7	18.3	17.4	9.9	9.1	8.6	17.0	16.6	15.7	18.8	18.6	17.5	10.8	8.6	9.5	11.9	9.7	10.6
29	ST6T	16.9	18.5	14.9	8.7	10.5	6.6	15.0	16.7	13.0	16.9	18.5	14.9	10.5	12.0	8.4	11.4	13.1	9.5
30	101S	18.4	17.8	17.7	9.3	8.6	8.6	16.5	15.7	15.8	18.5	17.9	17.8	8.4	7.2	7.7	10.2	9.1	9.5

Table 17 Difference between variable (SIMT) and fixed test signal at judged equal annoyance using calculated metrics.

ID #	Abbr.	TAVPNL	MXMPNL	EPNL(NT)	TAVPNLT	MXMPNLT	EPNL	TAVLLZ	MXMLLZ	LLZSEL	TAVPLS	MXMPLS	PLSSEL
1	101L	7.4	6.0	6.1	6.9	5.6	5.6	4.4	3.0	3.1	8.0	7.0	6.7
2	101T	6.4	6.4	4.5	5.4	5.9	3.6	3.5	3.1	1.7	6.2	6.1	4.4
3	707L	9.1	9.1	7.8	8.2	8.8	6.9	6.6	5.7	5.3	10.3	10.4	9.0
4	727L	6.3	5.9	6.1	5.6	5.5	5.4	3.5	2.9	3.2	6.0	5.7	5.8
5	727T	6.0	6.4	4.6	5.4	5.6	3.9	3.0	2.9	1.4	5.6	6.2	4.2
6	737L	3.2	2.3	2.5	2.5	1.4	1.8	0.2	-0.7	-0.6	3.0	2.2	2.3
7	737T	6.6	7.0	4.4	5.9	6.0	3.7	4.0	3.9	1.8	6.2	6.6	4.0
8	747L	7.0	7.3	5.2	5.8	5.3	3.9	4.4	4.7	2.5	8.1	8.9	6.3
9	747T	4.5	4.5	2.9	3.5	3.1	1.8	2.9	2.2	1.1	4.5	4.6	2.8
10	757L	7.5	6.8	6.4	7.2	6.5	6.1	5.9	4.8	4.8	8.2	7.6	7.1
11	757T	8.5	8.7	6.5	7.7	8.2	5.9	5.0	5.2	3.0	8.0	8.8	6.1
12	767L	8.1	8.5	6.4	7.3	7.2	5.6	5.1	5.3	3.5	9.0	10.1	7.4
13	767T	8.6	9.5	6.6	8.2	9.0	6.3	6.1	6.5	4.0	8.0	9.0	6.0
14	777T	7.8	8.2	6.0	7.1	7.5	5.2	5.3	5.0	3.4	7.4	7.7	5.5
15	B1BF	5.4	4.6	6.0	4.9	3.7	5.4	3.0	2.4	3.6	4.9	4.3	5.6
16	DS8T	5.2	4.3	2.4	4.1	3.2	1.3	3.8	3.5	0.9	5.4	4.4	2.6
17	D10L	7.8	6.5	6.5	7.2	5.8	5.9	5.3	4.7	4.0	8.9	7.9	7.6
18	D10T	7.1	7.7	5.5	6.1	6.9	4.4	4.5	4.8	2.8	7.1	7.8	5.4
19	DC7L	5.6	4.0	4.4	5.3	3.6	4.0	2.7	0.8	1.4	5.6	4.1	4.3
20	DC8T	6.0	6.0	3.7	5.7	5.3	3.4	3.4	3.4	1.1	5.7	5.6	3.4
21	F11F	7.9	6.5	10.3	7.0	5.1	9.2	5.0	3.9	7.3	7.6	6.2	10.0
22	J31L	9.5	8.2	6.8	8.4	7.0	5.7	5.6	4.3	2.9	9.7	8.9	7.0
23	J31T	3.7	2.2	1.2	1.3	-0.4	-1.2	3.6	2.8	1.1	4.4	3.1	2.0
24	M11L	6.7	6.2	5.2	6.2	6.3	4.7	3.8	3.5	2.3	7.6	7.4	6.1
25	M11T	7.3	6.4	5.9	6.9	5.3	5.4	4.0	3.0	2.4	6.9	6.1	5.4
26	M82T	5.9	7.5	3.4	5.5	7.3	3.0	3.6	4.7	1.0	5.5	7.0	3.0
27	SIMT	-1.0	-0.9	-0.7	-0.9	-1.0	-0.8	-0.8	-0.3	-0.5	-0.9	-0.7	-0.6
28	ST5L	9.6	7.1	8.3	9.2	5.9	7.9	6.4	4.9	5.1	10.3	8.3	9.0
29	ST6T	9.4	10.7	7.4	9.2	10.8	7.3	5.6	6.7	3.6	10.4	12.2	8.4
30	101S	8.1	6.7	7.4	6.3	4.8	5.6	7.1	6.2	6.4	9.5	8.7	8.8

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Thirty audiometrically screened test participants judged the relative annoyance of two comparison (variable level) signals and thirty standard (fixed level) signals in an adaptive paired comparison psychoacoustic study. The signal ensemble included commuter, Stage II and Stage III aircraft overflights, as well as synthesized aircraft noise signatures. All test signals were presented for judgment as heard outdoors, in the presence of continuous background noise, under free-field listening conditions in an anechoic chamber. Analyses of the performance of 30 noise metrics as predictors of these annoyance judgments confirmed that the more complex metrics were generally more accurate and precise predictors than the simpler methods. EPNL was slightly less accurage and precise as a predictor of the annoyance judgments than a duration-adjusted variant of Zwicker's Loudness Level.

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